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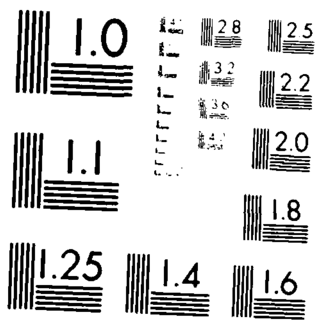

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A TOTAL COST ANALYSIS OF USING SURFACE TRANSPORTATION AND ADDITIONAL INVENTORY VERSUS AIR TRANSPORTATION TO SUPPORT C-130-7 ENGINE DEMAND IN EUROPE

Ernest L. Davis, Captain, USAF
William Simmons, Captain, USAF

LSSR 84-82

DEPARTMENT OF THE AIR FORCE
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DOD cost estimates for transportation are expected to increase considerably faster than the estimated rate of inflation. Because of the expected transportation cost increases, the need for more economical means of moving cargo overseas is of increasing importance. This research explores the possibility of increasing inventory assets and using surface transportation modes to move cargo in bulk as opposed to moving single items by air. A total cost model was developed to be used as a guide in determining the cost trade-off in comparing the surface mode with increased inventory versus air transportation. This model was then applied to the movement of C-130-7 aircraft engines from Kelly AFB, Texas to Rhein Main AB, Germany. The analysis revealed that under expected forecasts, more than half the cost of moving the engines by air could be saved by changing to surface modes and adding pipeline inventory which provides additional assets that could prove to be very critical during wartime. Thus, the authors concluded that DOD could realize considerable savings in transportation costs by building an inventory and using more surface transportation for overseas cargo movement.

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A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

Ernest L. Davis, B.S.
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William Simmons, B.S.
Captain, USAF

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This thesis, written by

Captain Ernest L. Davis

and

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has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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Thomas C. Harrington

COMMITTEE CHAIRMAN

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CHAPTER I

BACKGROUND

Transportation systems provide utility value to resources by moving the right thing to the right place at the right time. Therefore, defense transportation systems, as a major element in the Air Force logistics system, provide the vital link between procurement, supply, maintenance and user activities (18:87).

Transportation managers look to the future with some concern because the cost of procuring transportation to provide the resource utility is projected to increase faster than the rate of inflation. Specifically, the price of fuel is projected to increase approximately 14 percent per year through 1990, while the annual rate of inflation is estimated to be 8 percent through the same year (25). Since fuel is a major driver in the cost of transportation, fuel price escalation could result in a similar increase in the cost of transportation. At the 14 percent annual rate of increase, the average cost of moving a short ton of freight would be $726 in 1990, compared to $196 in 1980 (25).

The anticipated rise in the cost of transportation relative to the rate of inflation could impact the logistics system in a variety of ways. For example, the Air Force logistics system frequently relies upon premium air transportation modes combined with little or no inventory to support a deployed weapon system. As premium transportation costs increase relative to the cost of inventory, the point may be reached where larger inventories coupled with volume surface movements may be less costly than procurement of premium transportation, especially for overseas shipments. It is important to note that transportation mode selection decisions cannot be made in isolation of inventory, as well as other distribution element decisions. That is, to provide the same level of customer service, expressed in item availability terms, inventory must be expanded when slow transportation modes are used in lieu of premium transportation.

Problem Statement

A total distribution cost analysis needs to be performed for determining the appropriate transportation mode and associated inventory strategy in support of selected deployed weapon systems. The trade-off analysis becomes more critical in view of the anticipated increase in transportation costs relative to the cost of inventory.

Research Objectives

The following objectives provided the guidance needed to compare transportation and inventory costs associated with various modes and inventory strategies in order to determine the most economical method of distribution for deployed weapon systems.

1) Identify the relevant costs of transportation associated with the air and surface movement of DOD cargo between CONUS and overseas locations.

2) Identify the relevant costs of acquiring and storing additional items necessary to provide an established level of customer service when surface transportation is used in lieu of premium air transportation.

3) Perform a trade-off analysis between the total transportation, acquisition and inventory costs associated with the air transportation/no inventory and surface transportation/inventory strategies.

Scope

The focus of this thesis involved the determination of the minimum cost distribution system for C-130-7 aircraft engines deployed in support of the two C-130 aircraft squadrons at Rhein-Main AB, Germany.

Currently, C-130 engines requiring depot maintenance are shipped by air from Rhein-Main AB, Germany, to Kelly Air Force Base, Texas. Once the engines are repaired, they are returned to Rhein-Main AB by air transportation. Each year an average of 52 C-130-7 engines are moved in this distribution system (19).

As an alternative to the air shipment of individual engines, it is proposed that less costly surface transportation modes be used for C-130 engines. Both break-bulk and containership surface modes are considered for movement of the engines between Europe and the CONUS. However, in order to provide the same level of customer service in terms of engine availability, an inventory of additional C-130 engines would be needed when the slower surface modes are used. This is necessary to account for the increase in the transportation pipeline time associated with the slower methods of transportation.

The objectives of this research were then applied to the study of these alternative ways of supporting the C-130 engine program at Rhein-Main AB, Germany.

Assumptions

Although the following assumptions will be general in nature, their pertinence provides the foundation upon which this thesis is built.

1) The Department of Defense desires to minimize total transportation cost, using the available transportation modes.

2) Restrictions will be placed on the use of containers or break-bulk shipments in determining the most economical method of shipment.

3) The containers used in transporting DOD cargo will be 20 foot or 40 foot, depending on the most economical device used for shipment.

4) This research specifies a time limit which is

requirements. Ideally, station location, route structure and cargo load capacity will represent variables that must be included in the formulation of the optimal system structure.

3) A comparison between containerized and break-bulk shipments will be made in determining cost optimization. The determination between both types of shipments will involve the number of shipments per year, the number of engines to be shipped at any one time and the cost associated with such shipments.

4) The criteria involving mode selection and the type of inventory policy used will be the determining factors between a fast mode of transportation as opposed to a slower mode. Cost/time trade-offs will have to be made in acquiring the most economical cost available.

5) This study will focus on peace time requirements in obtaining the necessary quantity of C-130-7 engines from Kelly AFB, Texas, to Rhein-Main AB, Germany, using the most economical transportation modes available.

Research Question

The following research question was developed to provide direction for this thesis: At what point in time does the cost of premium transportation for C-130-7 engines exceed the cost of surface transportation coupled with the required additional C-130 engine inventory?

estimated to be from the present through the year 1996. At the end of this particular time interval, the C-130 aircraft is expected to be replaced by the C-17 or the C-XX aircraft.

The critical assumption in this study concerns the cost criteria for determining the most economical transportation modes. The assumption is based n the concept that the Department of Defense does, in fact, intend to minimize transportation costs. With excessive fuel and transportation costs steadily on the rise, a more economical means of transporting DOD cargo must be considered.

Brigadier General Powers, Director of Transportation HQ USAF, has stated the need to examine transportation within the Air Force environment (25). It is anticipated that, in the event of an emergency, the requirements for men and material will increase, which will warrant use of the most economical modes available.

Limitations

1) The total cost research models will concentrate on the choice between air and surface transportation modes in minimizing transportation costs in reference to the transshipment of C-130-7 engines between Kelly Air Force Base, Texas, and Rhein-Main Air Base, Germany.

2) The research models will be used to assess the most economical means of transporting (deploying) a major weapon system to an overseas location, in meeting peace time

Literature Review

Introduction

The first part of this section discusses the major concerns of the Department of Defense in finding alternative ways to transport cargo from CONUS to overseas locations. Concern will be laced on the high cost of fuels as it relates to total transportation costs and a brief discussion on the reasons why fuel costs are steadily increasing. This section will also respond to the question: "How well can the U.S. support personnel and equipment, in overseas areas while maintaining an economical, effective, and efficient transportation network?"

Improvements in transportation facilities will also be discussed as they relate to development of optimal material handling systems to meet the needs of DOD customers. The use of a containerized system will be introduced along with the advantages it has over break-bulk movement. In response to proven cost savings associated with containerization, the further development of this system can cut costs as well as improve handling across the various modes of transportation. The construction of the container and the various sizes used, in accommodating specific size shipments, will play an important factor in determining an optimal transportation system.

A considerable amount of cargo is transported by the airlift mode due to its speed and the benefit it provides

Justification

While cargo movement requirements have declined since the United States forces left Vietnam, rising transportation costs have caused the DOD to spend roughly the same amount of dollars to move less cargo. This being the case, the U.S. has recognized that it must economize on transportation costs at every possible opportunity. An emerging area of concern to the DOD is the intermodality or shipment of cargo from point to point by more than one means of transport, in hope of finding the most optimal means available. The advent of containers and the emphasis on fast, economical, through movement has brought to the forefront a number of problems only dimly foreseen a few years ago. The excessive increase in fuel prices and transportation costs has forced the DOD to seek these more economical means of transporting cargo, while at the same time, maintaining its flexibility and responsiveness to all DOD users.

The Defense Transportation System is big business which is effected by inflation, the high cost of fuel and the changes taking place in the ever increasing transportation industry. It is imperative that DOD keep pace with these changes to ensure that they will be able to respond to all necessary requirements in meeting transportation needs anywhere in the world at the lowest possible cost (12:220).

in eliminating the need for acquiring excessive inventory. However, the presence of fuel cost increases could change this pattern considerably. More emphasis may have to be placed on limiting the use of air transportation in exchange for increased inventory at various supply locations. Therefore, a comparison will be discussed concerning the use of sea versus air transportation as an aid in reducing total transportation costs. Air transportation will always be a key factor in commodity movement; but in combining two or more surface transport modes, it may be possible to not only produce a total transportation, acquisition and inventory cost savings with increased inventory levels, but also decrease ordering, processing and other related cost elements.

A brief discussion on break-even analysis will be presented as it relates to the comparison of alternative distribution systems. In this research, break-even analysis is used for determining at what point in time the costs of one system used to satisfy C-130-7 engine distribution will be less than another.

Finally, the use and description of the total cost model will be presented. The total cost model is made up of various cost components which, when combined, produce an overall system cost. The components of this model are: the inventory carrying cost which can include capital cost, inventory service cost and storage space cost elements;

transportation costs; and item acquisition costs.

Overview

In recent years, the increase in cargo movement from various locations around the world, coupled with substantial increases in transportation fuel cost, have forced the Department of Defense to initiate a number of studies in determining more economical means in which to ship different commodities of cargo (25). A thorough understanding of the transportation system is a prerequisite to successful decision making, which involves the selection of a transport mode to meet a movement requirement. To assist us in our understanding, it is important to appreciate the impact of the high cost of energy on the transportation system.

Transportation accounts for over half of the petroleum consumed in the United States. Prior to the 1973-1974 Arab oil embargo, the use of petroleum by the transportation sector has been rising at a tremendous rate due to such things as increased vehicle miles and ton-miles of freight transportation per capita, shifts towards more energy intensive modes, and the increased use of petroleum relative to other energy sources (16:169).

During and after the oil embargo, the federal government adopted a number of policies to conserve fuel in the transportation sector. A number of these policies were intended to increase energy efficiency within each mode of transportation, such as motor carriers and shipping. Others were intended to shift transportation demand from energy-intensive to energy efficient modes (16:170). Within the defense transportation system, the use of energy efficient modes capable of moving large quantities of cargo and equipment is essential during wartime operations.

It is known that sustaining logistics is a necessary ingredient for winning any armed conflict. While much has been said and done about the need to rapidly deploy troops, equipment and supplies to troubled spots around the world, the importance of keeping them resupplied, once they are engaged in combat, must not be neglected. Because of the rapid response dictated by wartime planning scenarios, strategic airlift is essential for the initial deployment. The United States Air Force, through the Military Airlift Command (MAC), is charged with this responsibility. However, when it comes to sustaining large military operations, airlift capabilities become overtaxed--not only from a standpoint of not being able to move enough supplies on a continuous basis, but also from the standpoint of fuel costs. In this case, ocean transportation will be the means by which the heavy logistic items will be moved, because of lower fuel costs and its ability to move large amounts of cargo at any one time (24:45).

Another point which must be kept in mind, with respect to transportation costs, is that many of the world's potential trouble spots are not equipped to handle the off-loading of large ships at a rate sufficient enough to keep up with the possible demands. Many bottlenecks will occur if transport ships are tied up offshore awaiting off-loading. Not only will this hold up the supply line, but increased transportation costs will be incurred due to the use of other higher cost transport modes for continuing resupply and the payment of excessive port fees.

To eliminate these problems and assist in cutting transportation costs, major improvements in port facilities will aid in the ability to handle the bulk of freight going to these countries and to allow for increased tonnage movement well above prescribed present day levels (9:17). In summation, the Department of Defense is relying on a highly developed transportation system, incorporating the most modern methods in ocean shipping, to guarantee American personnel continued support in the most economical manner (17:38).

Containerization

The key to the efficient movement of military support cargo is containerization, which is a freight handling system that has transformed world trade in the short space of 25 years. Containerization involves standardized freight handling by using containers that are adaptable to trucks, rail and ship transportation modes. Containerization has enabled the United States Department of Defense to cut transportation, loss and damage costs, as well as save time in cargo handling. Today, approximately 500 container loads are delivered each week by container carriers, like Sea Land, to the continental ports of Rotterdam, the Netherlands, Bremerhaven, Germany, and Algeciras, Spain (17:41).

The National Maritime Day 1981 witnessed an era when more than 75 percent of the world's cargo compatible with containerized transport is being shipped by an industry that did not even exist a quarter-century ago. It saw a world containership fleet, that today numbers close to 1500 vessels, and a world container inventory in excess of two million units, tailored to carry a full range of commodities in international commerce. It also saw countless port facilities around the globe dedicated to container shipping (7: 12; 23:113).

Containerization can also be looked at as a system that is aimed at introducing continuity into the shipping process. The container unit is a receptacle of flexible covering in the shape of a large parellelogram, made of steel, an alloy or plywood. Its size is standardized at 10, 20, 30 or 40 feet in length. Two containers 10 feet long can fit into a 20 foot container and two 20 foot containers can fit into a 40 foot container. The loads are thus adapted to ships, railway cars or trucks and to the loading equipment. Although it is not necessary to break down cargo during the loading process, the container does require handling and poses the problem of integrating land and ocean transport (2:14).

In meeting the objective to reduce costs, a pre-planned land system was developed to eliminate the need for rehandling and warehousing that would be necessary if products were shipped in single commodity or break-bulk units. At the receiver's end, custom loading allows space and inventory reductions and cuts cost and waste (17:41). For single products moving in large quantities to an ultimate user, containers are loaded at the manufacturer's or vendor's site rather than at a military installation.

Although containers still encompass less than a two percent share of the overall freight traffic, the use of containers in international freight transportation is estimated at about 40 percent and in marine transportation, at an impressive 80 percent (9:18). Without question, the containership industry, pioneered largely through American efforts, has streamlined the transport of goods throughout the world. This industry has been instrumental in opening up new world markets. It has seen phenomenal growth over the past 25 years and has made dramatic strides both in technology and in the quality of service.

Assisting in the movement of containerized cargo is the Sea-Land giant SL-7 containership. These ships carry containerized, as well as break-bulk military cargo destined for U.S. troops located in areas such as Europe, the Mediterranean and the Far East. Introduced in 1973, the SL-7's are among the world's largest and fastest ships capable of attaining 33 knots cruising spped. Each ship is capable of carrying 1100 containers of 30 and 40 foot lengths.

Containerization, found in all areas of shipping, provides the advantages of a method that deals with the problem of cargo transfers far more effectively than methods used to ship break-bulk cargo.

Air Transportation

Air transport's primary advantage is obviously speed. This speed is all the more attractive because it multiplies benefits. Time saved is a source of cost savings in itself, but it also has a direct impact on the amount of capital tied up in the cargo during shipment. The result adds up to considerable amounts of money when transportation time is reduced from several weeks, or even several months, to a few days. The problems associated with the storage and care of goods in transit, as well as the costs of storage and care of cargo, can be reduced to a minimum by rapid air transport. Air freight is a precious link in the distribution chain connecting shippers and consumers, whatever the distance separating them (2:92).

Another advantage of air freight is the quality of goods delivered. In the cargo compartment of an airplane, cargo or goods are safe from weather and the risks of theft and damage posed by surface transport during transfer and storage time, which the aircraft generally eliminates. The caution that necessarily dominates all ground operations involving an airplane has a positive effect on the quality of service and attention paid to freight during loading and unloading. This, in turn, has a beneficial effect on insurance rates. Air freight is, by far, cheaper to insure than the same freight shipped by ground or ocean transportation (2:93).

Sea Versus Air Transportation

It was found that the total cost of cargo movement by sea represented 25 percent of that experienced on air shipments. In consequence, a shift in the movement of cargo to the sealift mode is becoming more and more commonplace. Shipping lines are a serious threat to the air cargo industry, because of a freighter's ability to carry more cargo per ton mile as compared to the tonnage capacity of a large cargo aircraft (24:45). For example, in an all cargo configuration, a B-747 aircraft can carry over 100 tons, which is about one percent of the tonnage capacity of a small ocean-going freighter.

On the other hand, air transportation has the speed advantage over sealift. In the above example the B-747 can cover 25 to 35 times as much distance as the ocean vessel in one hour. Hence, if ton-miles per hour were the only criteria for comparison, three or four B-747's can displace the need for one entire small freighter.

In the final analysis, air remains an important part of continuing trans-oceanic shipping strategy. While ocean volume is still increasing, it is ultimately anticipated that the modal mix will level off at 85 percent by sea and 15 percent by air (24:45).

Modal Choice and Routing

The shipper's choice of mode is typically not a single choice of between water, rail, highway or air transport modes, but is an objective and subjective selection made from a mixture of modes, routes and schedules. In other words, modal choice and routing can be viewed as a set of sequential decisions made by the shipper. Shippers of various commodities should examine a number of factors or costs which they regard as relevant. For different commodities, different factors will take on greater or lesser importance. For one commodity, the weights given to each factor can be thought of as remaining constant over a particular network, and each link's rating can be determined on the basis of its particular performance characteristics. Once links are rated, paths can be sought to maximize the shipper's utility rating which will, in turn, minimize transportation costs (15:48).

Break-Even Analysis

One method for choosing between various transportation and inventory strategies to minimize the total costs of a distribution system is based on the principles of break-even analysis. Break-even analysis can be performed by graphic or mathematical methods. The dynamic approach can be organized to provide information concerning movement volumes at which a shipper should alter their logistics system, to relate costs of various systems at any point in time or to assess the impact of fixed costs on the selection of a logistics system to do a particular job. It goes beyond an analysis of the relative desirability of several logistics systems at a given point in time, which requires assumptions of static volumes of shipments, shipment characteristics or service characteristics. The dynamic approach of logistics systems analysis requires, as stated above, the measurement of all costs associated with the use of a system over the time period of interest, the separate identification of fixed and variable costs, and the computation of point of indifference between alternative systems (6:465).

Total Cost Concept

Total cost analysis provides a convenient vehicle for analyzing the cost considerations involved in selecting between a number of transportation and inventory strategy alternatives. Further, it requires the collection of the fixed and variable costs in such a manner that cost trade-offs can be identified. Total cost analysis can also be used to analyze many types of logistics systems, such as those using private transportation methods, special devices for information flow, varying numbers of storage facilities and others (6:469). Finally, total cost models provide the information necessary to perform a break-even analysis of alternative distribution systems.

In order to develop a cost-effective form of transportation and inventory distribution system, all associated costs should be fully identified, reported quickly and accurately, and be readily accessible for routine operations and long range planning. The objective in developing a more cost effective transportation and inventory system is to minimize the combination of each individual cost component. While there are many forms of total distribution cost models, the general model used in this study is:

Total Cost = transportation cost + inventory carrying cost + item acquisition cost

The Department of Defense should always examine ways to achieve the optimal cost-service mix without injecting any shortfalls which may hinder military responsiveness and effectiveness. For example, methods to reduce costs can include increased consolidation of cargo shipments, such as in containerized movement; r ggy-back routings; the use of common pick-up and delivery points; and more effective packaging (12:147).

The transportation and acquisition cost components of the total cost model used in this research will be discussed in the following chapters. The inventory carrying cost component will also be discussed in specific detail in the following chapters; however, a general discussion of inventory costs is provided next.

Inventory Carrying Cost

Inventory carrying costs can be thought of as those costs associated with the quantity of inventory stored, and include a number of different cost components. The need for an accurate assessment of inventory carrying cost, if the appropriate trade-offs are to be made, depends on the magnitude of these costs in the problem situation. In lieu of accurate and specific calculations, estimates are usually used when considering the cost of holding inventory, and these range from 12 percent to 35 percent of item value. These percentages are derived from traditional textbooks or from industrial averages. Most carrying cost percentages are nearer to 25 percent (12:240).

It is often the case that in many companies, inventory carrying costs are not calculated but only estimated. When these costs are calculated, the calculations generally include only the current interest rate plus such items as insurance and taxes (12:239).

Calculating Inventory Carrying Cost

In calculating inventory carrying cost, only those costs that vary with the quantity of inventory should be included. There are four major components involved in determining the inventory carrying cost in a transportation and distribution system. They are: capital costs, inventory service costs and storage space costs. A brief description of each component will be presented next.

Capital Costs. When inventory is obtained, it ties up money that can be used for other types of spending. Consequently, the opportunity cost of capital, which is the rate of return that could be realized from other uses of money, should be used in order to reflect accurately the true costs involved. In organizations where funds are distributed for specific purposes, a hurdle rate should be used as a cost of capital. A "hurdle rate" may be defined as the minimum rate of return on new major procurement items (12: 241).

Once the cost of money has been established, it is then necessary to determine the value of the inventory on which the inventory carrying cost is to be used. At this point, costing alternatives should be used. The two costing alternatives used are the direct costing method and the absorption costing method. The direct costing method is that method of cost accounting which is based upon the segregating of costs into fixed and variable components. This is done in order to exclude fixed costs of production from the inventory values. With absorption costing, otherwise known as full costing, fixed manufacturing overhead is inventoried (12:242).

Inventory Service Costs. These costs are comprised of taxes and insurance paid as a result of holding inventory. In a general sense, taxes vary directly with inventory levels. On the other hand, insurance rates are not proportional to inventory levels, since insurance is usually purchased to cover a certain value of an item over a specified period of time and revised periodically based on changes in total inventory levels (12:244).

The actual dollar amount spent on insurance and taxes during a specified period of time can be calculated as a percentage of the inventory value, and then added to the cost of money component of the carrying cost. If budgeted figures are available for the coming year, they can be used as a percentage of the inventory value based on the forecasted inventory level in order to provide a future-oriented carrying cost (12:244-245).

Storage Space Cost. Storage space cost is incurred when storing inventory type items within a specified building or location. The type of facilities used plays a major role in assessing related storage costs. Examples of the various facilities are: public warehouses, private warehouses, rented or leased warehouses. Public and leased warehouses usually contain variable cost components which vary with the amount of inventory stored. Private warehouses contain fixed cost components which do not vary in direct proportion to the amount of inventory held. Again, only those costs that vary with the quantity of inventory should be included in determining the inventory carrying costs.

Summary

We have presented the background, problem statement and objectives of this research effort. Chapter II will describe the methodology used to analyze the present and proposed distribution systems under study. A total cost model will be presented for the identification of the cost components necessary in evaluating the total costs of alternative systems. Chapter III includes a discussion of the results of our analysis, followed by the conclusions and recommendations in Chapter IV.

CHAPTER II

METHODOLOGY

Introduction

The principle objective of this research was to perform a trade-off analysis between the total transportation, acquisition and inventory costs associated with various distribution strategies to support C-130-7 engine demand in Europe. Two major strategies were investigated. The first strategy represents the current system of using air transportation of C-130-7 engines between Kelly AFB, Texas, and Rhein-Main AB, Germany. The second strategy proposes the use of containerships for the engine movement requirements. This strategy incorporates land and sea transportation modes for container movement, and requires an additional inventory of C-130-7 engines to provide the same level of customer service as the air transportation system. That is, the additional inventory is required to account for the slower intransit times of the surface transportation systems. This strategy involved the investigation of using both 20 and 40 foot containers for the intermodal surface movement of C-130-7 engines.

In order to determine the most economical method of distribution, it was necessary to examine the present and future costs directly related to the strategies under investigation. Thus, this research attempted to capture and compare the total costs of moving C-130-7 engines between Kelly AFB, Texas, and Rhein-Main AB, Germany, using both air and surface transportation modes.

The main thrust in evaluating the total cost of a distribution system is the introduction of the total cost concept. The total cost concept is the recognition that the logistics system should be defined broadly enough so that all relevant costs to a decision problem are considered in the decision process. In determining optimal transportation alternatives, a total cost model will be presented to assist in analyzing the system under study.

Research Model

The total cost model used in this study encompasses three basic cost components: fixed costs, variable transportation costs, and inventory carrying costs. These cost components will be examined and explained below.

Fixed Costs (FC)

Fixed costs can be defined as expenses which do not vary with the amount of service that is being offered. It is generally assumed that expenses for equipment, facilities, depreciation and taxes on these items are fixed (5:73). For this research, the fixed cost component includes the expenditures necessary for acquisition of additional C-130-7 engines required to fill the pipeline inventory when surface transportation is used in lieu of air transportation modes. Because surface transportation is slower relative to air transportation, additional pipeline inventories are necessary to provide the same level of customer service available with use of air transportation.

Variable Costs (VC)

Variable costs can be defined as those expenses which vary directly with the amount of service offered by a particular carrier. Transportation expenses that can be considered variable include, but are not limited to, fuel costs, equipment maintenance costs, labor costs and handling.

Inventory Carrying Costs (CC)

Carrying costs can be defined as the costs that are associated with the quantity of a particular item stored. The magnitude of these costs and the fact that various item levels are influenced by the configuration of the physical distribution system demonstrates the need for an accurate assessment of carrying costs, if the appropriate cost trade-offs are to be made (12:241).

Total Costs

Total costs emphasize the appraisal of all fixed costs, variable transportation costs and inventory carrying costs resulting from a decision to utilize a particular method of accomplishing each activity. Furthermore, it places emphasis on the analysis of the nature of change in these costs under varying conditions. The underlying principle of the concept advocates the avoidance of suboptimization of system components, that is, the optimization of one system component to the detriment of total system cost (12:36).

In summary, the following is the total cost model which was used in examining the total costs of various systems under investigation:

Total Cost = Fixed Cost + Transportation Variable Cost
+ Inventory Carrying Cost

Data Requirements

The variables used in developing the total cost model are classified as input (decision) variables and output (dependent) variables. The input variables are decision variables under the control of the decision maker, and the output variables are response variables which are a function of the input entities (20:15-16).

In the transportation systems under study, three variables are identified as independent. These variables are transportation costs, acquisition costs and inventory carrying costs.

Transportation costs are those costs associated with the movement of materials and equipment from point of origin to point of destination. These costs may include loading and unloading, packaging and damage, transit time, intransit loss or damage not covered by carrier liability, and traffic control. For this research, transportation rate tariffs for the various modes were used to represent the total of all of the separate cost components. Acquisition costs are those costs associated with purchasing or procuring an item or piece of equipment. These costs are usually sunk costs which cannot be recovered once the item or equipment is obtained. In this research, acquisition costs were computed for additional C-130-7 engines needed with the surface transportation strategy. Inventory carrying costs include only those costs that vary with the level of inventory stored, and can be categorized into the following groups:

1. Capital cost, which is the opportunity cost of capital multiplied by the variable out-of-pocket investment in inventory;

2. Storage space cost;

3. Inventory risk cost including obsolescence, damage, pilferage and relocation costs. Inventory carrying costs, as a proportion of average value of inventory on hand, have been estimated generally at 25 percent. For this research, inventory carrying costs were equated to those used for economic order quantity items in Air Force supply systems.

The output (dependent) variable is identified as the total cost component in the research model. Total cost is one measure of the transportation system under investigation, and it takes into consideration all transportation and related costs affected by the possible changes which may occur within a system.

Data Collection

The purpose of this section is to identify the primary sources utilized in obtaining all pertinent data necessary to develop the total cost models. The information concerning the C-130-7 engine weight and shipping dimensions was obtained from the Traffic Management Office, Kelly Air Force Base, Texas (4).

The policies and procedures pertaining to the number of engines authorized at Rhein-Main and shipment routing were obtained from the San Antonio Air Logistics Center, located at Kelly Air Force Base, Texas (19). The route structure provided information on the current flow of C-130 engines, the route segments connecting Kelly AFB and Rhein-Main AB, and the mode of transportation now being utilized to accomplish this task (19).

The required information on modal rates were obtained through telephone conversations with Traffic Management personnel and from published technical information. The primary data sources for airlift rates included the Military Airlift Command (MAC) Log Air Tariff, dated January 1982;

Air Force Regulation 76-11, U.S. Government Rate Tariffs, dated May 1981; and Traffic Management Office personnel at Wright-Patterson AFB, Ohio (3).

All surface rates, including land and sealift, were obtained through telephone conversations with Military Traffic Management Command personnel (10).

The container was used in this study for the purpose of consolidating the shipments of C-130 engines from origin to destination. In so doing, rate structures have been employed in hopes of reducing the overall costs incurred within the transportation system. The container rates were obtained from Military Traffic Management Command personnel at the water port of Bayonne, New Jersey (10; 22).

The additional information required to construct and evaluate the total cost model is the acquisition cost for the C-130-7 engine. This cost and other related information were obtained from the Propulsion Laboratory, located at Wright-Patterson AFB, Ohio (14). Intransit times for both surface and air transportation were obtained from HQ AFLC, also located at Wright-Patterson Air Force Base (13).

The above sources provided the information required to develop the total cost and break-even analysis models used in this study.

Total Cost Model Development

This section will describe the total cost model used for evaluating the two strategies of distribution. This model is linear in nature and will describe total costs for a specific method of moving C-130-7 engines to and from Europe.

The decision variables of the model are the transportation costs, engine acquisition costs, engine salvage value, carrying costs, and the discount factor/present value variables.

Transportation Costs

Transportation costs were determined for the present and proposed systems based on 1982 data. The authors then forecasted the costs over a 15 year period, from 1982-1996, using an annual increase of 14%, based on the estimated fuel cost increases from the Future Look '81 Conference (25). These costs were then discounted into present value, 1982 dollars, using a government recommended discount factor of 10 percent (1:82).

Acquisition Cost

In maintaining required customer service levels for the proposed surface transportation systems under study, additional C-130-7 engines would have to be acquired and added to the current inventory. Based on a 1982 cost of $91,000 per engine (14), a total acquisition cost would be calculated based on the total number of additional engines needed.

Salvage Value

The salvage value represents the amount of money that could be expected from disposition of engines under the assumption that the C-130 aircraft will be replaced by the C-X or C-XX, fifteen years into the future. In calculating this value, the authors applied the current engine acquisition cost, depreciated it over a 20 year period and assumed that the engine would be worth approximately 25 percent of its original cost after just 15 years of use. In order to obtain what was felt to be more in line with the criteria established in this study, the 25 percent salvage value was inflated by an annual rate of 8 percent over the 15 year period. This figure was then discounted using a 10 percent discount factor. The resulting amount was then applied as the salvage value for the C-130 engine at the 15 year point.

Inventory Carrying Cost

The Department of Defense does not normally consider carrying costs for major acquisition items in pipeline inventory models; however, the authors felt that some consideration should be given for carrying the additional engines required for the proposed system since there is additional storage and handling. In the absence of an existing method of calculating the carrying costs, the authors developed the following basic procedure. A carrying cost of 26 percent was applied to the annual straight-line depreciated acquisition costs for the C-130-7 engine. This percentage rate was extracted from AFM 67-1, Volume II, Part 2, page 11-4a, Carrying Costs for Economic Order Quantity Items. The resulting amount was then multiplied by the number of additional engines required. The computed carrying cost was then increased at an annual rate of eight percent to obtain the annual carrying cost to be used in this model. Finally, the annual carrying cost figure was discounted to 1982 present value dollars.

Inventory and Customer Service Level

The current inventory level at Rhein-Main Air Base, Germany, includes an authorization of 15 C-130-7 engines, with a 1982 predicted demand of 26 engines. The information concerning authorization levels was obtained from the C-130 Engine Systems Manager (19). This data was then combined with the average time required to move Priority I cargo from Kelly AFB to Rhein-Main AB to determine the average level of inventory based on a uniform usage rate, which maximizes customer service. This average inventory level was used as the required customer service level for both the present and proposed systems. For the purpose of comparing alternative systems, the authors established an arbitrary stock level of 50 engines to be positioned at Kelly AFB for use with the current system. This, in turn, enabled the study of the "total pipeline" effect on inventory, as it applies to this research.

One objective of the proposed system is to provide a level of service that is equal to or better than the system presently in use. This required the acquisition of additional C-130 engines which were added to the present levels to offset the increase in the time required to move engines between Kelly AFB and Rhein-Main AB.

Intransit Delivery Time Criteria

One of the basic factors used in achieving a well balanced stock position is a reasonably predictable order and shipping time (O&ST). The O&ST, literally the "pipeline" time, represents a period from the time the requisition is entered into the supply system until the required material is received by the requisition activity (23:99).

The O&ST, when translated into quantities of items, becomes a significant factor in the calculation of the operating stock level. An operating stock level is the quantity of C-130-7 engines necessary to meet demands over a period of time. The quantity required is calculated from past demands over a similar time period, the number of engine-days in the "pipeline," and a safety level quantity to compensate for variations in demands or shipping delays (23:99).

The intransit delivery time used in this model was determined by taking the average monthly order and shipping time for the period January 1980 to June 1982, for cargo movement from Kelly Air Force Base to a designated European destination. To determine the intransit shipping time for airlift movement, the data for Priority I shipments were used. For surface movement, Priorities II and III shipment data were used (13). Actual O&ST data was used in lieu of standard data to better represent the environment under study. It should be noted, for the benefit of the reader, that standard times are available.

One of the factors in calculating standard order and shipping time is the Standard Delivery Date (SDD). The SDD is the maximum standard terminal date by which the normal processing and shipping time in the logistics system will permit the receipt and recording of the requested material by the requisitioning agency or consignee. The SDD can be computed by adding the appropriate time standards in columns 3 and 4, of Figure 2-1 below, to the date of requisition. Of course, the geographic location and the priority group will be the governing factors (23:100).

Total Cost Computation

For the present and proposed systems under study, the total costs were calculated by a summation of the acquisition cost, transportation costs and carrying costs for each year of occurrence. Following this, a government recommended 10 percent present value factor was applied to these cost totals to obtain the annual discounted costs for each

Priority Group	Priority Designation	CONUS SDD	Overseas SDD
(1)	(2)	(3)	(4)
1	01 - 03	8 days	12 or 13 days
2	04 - 08	12 days	16 or 17 days
3	09 - 15	31 days	69 to 84 days

Fig. 2-1. Standard Delivery Dates

system. Finally, the annual discounted costs of each system were summed to arrive at the net present value cost of each system.

Total Cost Model Validation

This section discusses the techniques used for validating the total cost model.

Validation of the transportation cost component of the research model, as applied to the current system, was accomplished by computing the transportation costs per engine from data obtained from the Traffic Management Office at Wright-Patterson Air Force Base, Ohio. These costs were compared to the actual transportation costs obtained from the Traffic Management Office at Kelly Air Force Base, Texas (4). It was discovered that the actual costs were 99.5 percent of the calculated costs. This difference was attributed to the rounding of the calculated costs to the nearest dollar. It can then be assumed that the model is very accurate in reproducing the actual cost of the current system.

In reference to the proposed system, there was no real system with which to make a comparison. In order to validate the transportation costs of the total cost model for the proposed system, Mr. Joe Kelly (11) of Bayonne's International Transportation Rates Division was asked to calculate the transportation costs to which the authors' calculated rates were compared. Bayonne's calculated costs were found to be 14.36 percent less than those of the authors. An investigation indicated that the major difference in costs was attributed to the fact that the costs used at Bayonne were the lowest cost possible in each case, whereas the authors chose to take an average of several cost variables quoted by different carriers. Since the objective of this study is to determine if the proposed system is more economical than the current system, the authors chose to use the higher rates for the proposed system in an effort to ensure that any error made would be in favor of the current system.

Break-Even Analysis

Break-even analysis is another way to analyze data for specific planning and controlling purposes. In this study, break-even analysis was used to determine the most cost effective way of supporting the required C-130-7 engine demand in Europe. The important usefulness of break-even points lies in the process of forecasting and controlling costs. In itself, a break-even point moves only with changing conditions and, in moving, flashes a warning. To ensure follow-through from this warning requires a detailed control employing the time concepts supporting the break-even goal, clearly expressed as goals at all management decision levels.

Figure 2-2 depicts the break-even analysis chart designed in this study to examine at what point, within a

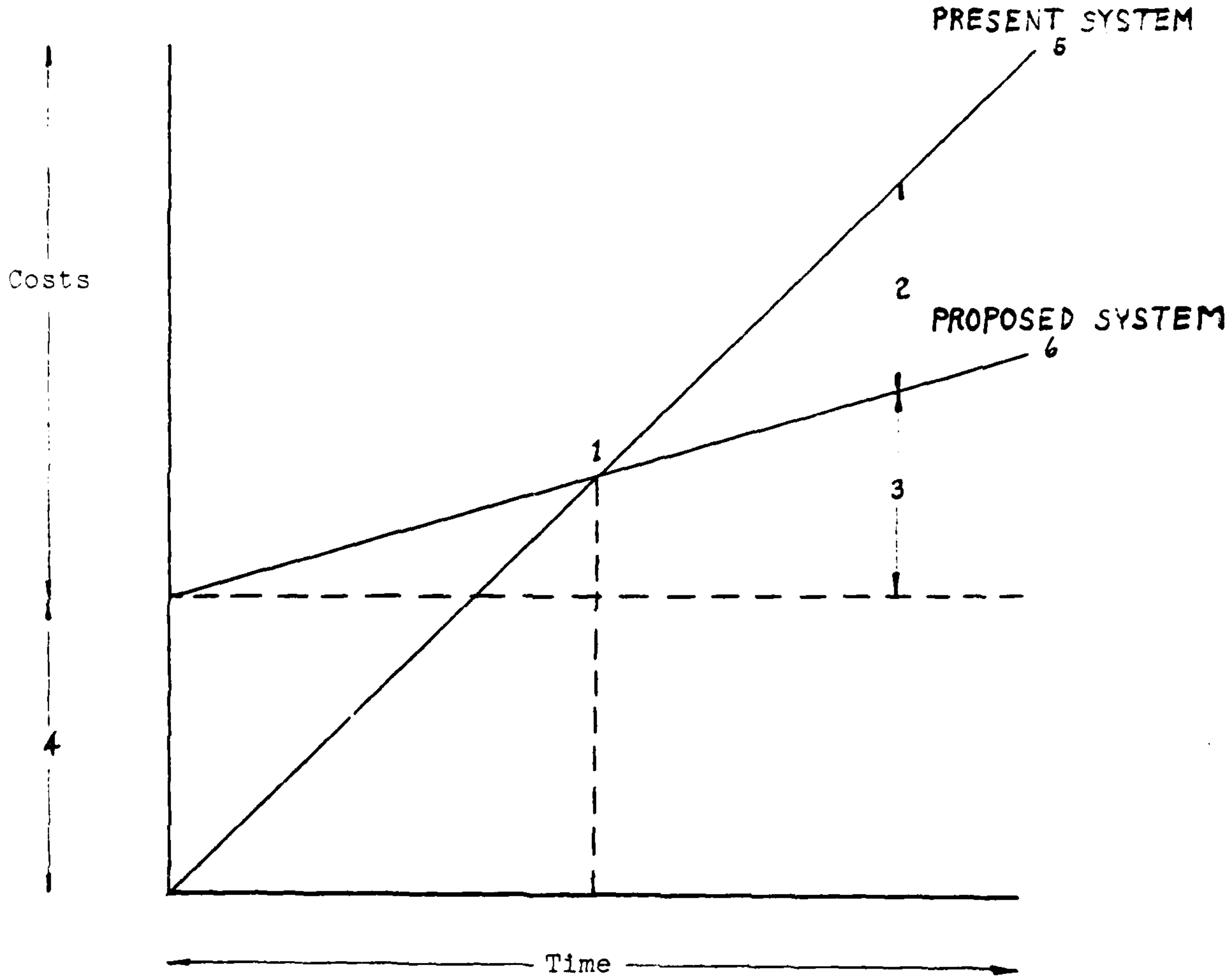

Fig. 2-2. Break-Even Analysis Chart

fifteen year period, the proposed system will become more cost effective than the present system.

The items of significance in the break-even chart are:

1) the break-even point

2) the potential cost savings above the break-even point

3) variable cost rates as an approximation of "direct" or out-of-pocket costs (costs which vary with volume)

4) fixed cost (cost of additional engines)

5) total cost for present system

6) total cost for proposed system

Sensitivity Analysis

Sensitivity analysis was performed to determine how sensitive the results of the total cost models were to changes in the following two key input variables. First, C-130-7 engine demand was varied at 10 percent above and 10 percent below the baseline rate of 26 engines per year. Second, the forecasted 14 percent rate of transportation cost inflation was changed up to 20 percent and down to 8 percent.

In addition, the surface transportation routes were varied to examine the effects of utilizing alternative ports of embarkation and debarkation. Finally, in order to better assess the costs and benefits of containerization, a surface transportation system incorporating break-bulk shipping was investigated. As with the use of 20 and 40 foot containers, this system required an additional inventory of C-130-7 engines to account for the slower intransit times of break-bulk vessels.

Summary

This chapter described the methodology used to analyze the present and proposed systems involved in this research effort. A total cost model was developed and used to study the cost differences between the two systems. As indicated in this chapter, the majority of data came from the Traffic Management Office, Kelly AFB, Texas; San Antonio Air Logistics Center, San Antonio, Texas; and the Traffic Management Office, Wright-Patterson AFB, Ohio. The actual transportation costs were calculated from the data obtained from Kelly AFB and Wright-Patterson AFB and were found to be 99.93 percent accurate. This effort was accomplished in order to verify the accuracy of the data used and to increase the reliability of the model and its results.

CHAPTER III

MODEL MANIPULATION AND RESULTS

Introduction

This chapter describes how the total cost models were developed for analysis of alternative methods of transporting C-130-7 engines between the San Antonio Air Logistics Center at Kelly AFB, Texas, and the C-130 bed-down base at Rhein-Main AB, Germany. The chapter begins with a presentation of how the data was collected, analyzed and transformed into the total cost models for the two major strategies under investigation. The first strategy represents the current system of using air transportation for engine movement. The second strategy proposes the use of containers to move the engines through intermodal surface transportation systems. For this strategy, both 20 and 40 foot container systems are analyzed. Total costs for each of the major strategies are then compared to determine the most economical distribution system. The chapter concludes with a discussion of the sensitivity analysis performed to determine the effects of changes to demand forecasts, transportation rates, and transportation routes. Under the sensitivity analysis phase of this research, the use of breakbulk shipping in lieu of containerization was also investigated.

Data Analysis

Table 3-1 provides the data parameters necessary to construct the total cost models. The initial step in analyzing the data was to establish the average level of customer service at Rhein-Main AB, Germany, and the average inventory levels at the Rhein-Main AB and Kelly Air Force Base locations. This was accomplished by analysis of the average transit time, the minimum inventory levels and the estimated engine demand for 1982. Assuming a uniform usage rate of 26 engines per year at Rhein-Main AB, and an engine being ordered from the San Antonio Air Logistics Center Depot every time an engine requires major overhaul at Rhein-Main, an average on-hand level of 14.24 engines was established at Rhein-Main under the current air transportation system. The minimum inventory level, in this case, was estimated to be 14 engines. An average inventory level of 49.31 engines was established at the San Antonio Air Logistics Center at Kelly AFB, also under the current system. The minimum inventory level at Kelly AFB was estimated to be 49 engines. Figure 3-1 illustrates the data analyzed to establish the minimum and average inventory levels for the current air transportation system. These levels were then used to establish the customer service level criteria for the proposed systems under investigation.

Using the data in Figure 3-2, it was determined that in order to satisfy the customer service criteria established

TABLE 3-1

DATA PARAMETERS

Air Rates:

Log Air from Kelly to Tinker	16 cents per pound
MAC from Tinker to Rhein-Main	1.478 dollars per pound

Engine Dimensions in Shipping Container

110 inches long, 46 inches wide, 49 inches high, and 2600 pounds

3.6 measurement tons

Truck Rates:

From Kelly to:	Galveston	New Orleans	Charleston
Break-Bulk	5.84/cwt	4.17/cwt	9.12/cwt
20' container	.89/mile	.89/mile	.89/mile
40' container	.93/mile	.93/mile	.93/mile

Ocean Rates per Measurement Ton:

From Galveston or New Orleans to Europe:		Port Handling Charges
Break-Bulk	$68.57	$44.61
20' container	$74	$ 3.76
40' container	$58	$ 3.76
From Charleston to Europe:		
Break-Bulk	$75.77	$44.61
20' container	$64	$ 3.76
40' container	$52	$ 3.76

TABLE 3-1 - Continued

Truck Rates per Measurement Ton		Port Handling Charges
From Bremerhaven to Rhein-Main	$40.53	$65.56
From Rotterdam to Rhein-Main	$27.60	$43.13

Average Travel Times

Air	11 days
Surface	56 days

20 foot container priced at 30 measurement tons

40 foot container priced at 60 measurement tons

Inventory Levels:

Rhein-Main	15 engines
Kelly	50 engines

Engine Cost: $91,000 each

Salvage Value: $15,821 each, after 15 years use

Demand	= 26 engines per year	276 days - 14 engines on hand
365/26	= order 1 engine every 14 days	
Repairables	= 26 engines per year	89 days - 15 engines on hand
Demand + Repairables	= 52 engines transported per year	
		Average on hand - 14.24

RHEIN-MAIN

# engines on hand	15	14	15	14	15	14	15	14	15	14	15	14	15	14	15
Day engine arrives			25		39		53		67		81		95		109
Day engine breaks		14		28		42		56		70		84		98	
Day engine ordered		14		28		42		56		70		84		98	
Day engine shipped		14		28		42		56		70		84		98	
Day in cycle	1	14		28		42		56		70		84		98	

# engines on hand	14	15	14	15	14	15	14	15	14	15	14	15
Day engine arrives		123		137		151		165		179		193
Day engine breaks	112		126		140		154		168		182	
Day engine ordered	112		126		140		154		168		182	
Day engine shipped	112		126		140		154		168		182	
Day in cycle	112		126		140		154		168		182	

Fig. 3-1. Current System: Air Transportation

RHEIN-MAIN

# engines on hand	14	15	14	15	14	15	14	15	14	15	14	15	
Day engine arrives		207		221		235		249		263		277	
Day engine breaks	196		210		224		238		252		266		
Day engine ordered	196		210		224		238		252		266		
Day engine shipped	196		210		224		238		252		266		
Day in cycle	196		210		224		238		252		266		
# engines on hand	14	15	14	15	14	15	14	15	14	15	14	15	14
Day engine arrives		291		305		318		333		347		361	
Day engine breaks	280		294		308		322		336		350		364
Day engine ordered	280		294		308		322		336		350		364
Day engine shipped	280		294		308		322		336		350		364
Day in cycle	280		294		308		322		336		350		364

Fig. 3-1 - Continued

KELLY

276 days - 49 engines on hand
89 days - 50 engines on hand
Average on hand = 49.24

# engines on hand	50	49	50	49	50	49	50	49	50	49	50	49	50	49	50
Day engine arrives			25		39		53		67		81		95		109
Day engine shipped		14		28		42		56		70		84		98	
Day in cycle		14		28		42		56		70		84		98	

# engines on hand	49	50	49	50	49	50	49	50	49	50	49	50
Day engine arrives		123		137		151		165		179		193
Day engine shipped	112		126		140		154		168		182	
Day in cycle	112		126		140		154		168		182	

# engines on hand	49	50	49	50	49	50	49	50	49	50	49	50
Day engine arrives		207		221		235		249		263		277
Day engine shipped	196		210		224		238		252		266	
Day in cycle	196		210		224		238		252		266	

Fig. 3-1 - Continued

# engines on hand	49	50	49	50	49	50	49	50	49	50	49	50	49
Day engine arrives		291		305		318		333		347		361	
Day engine shipped	280		294		308		322		336		350		364
Day in cycle	280		294		308		322		336		350		364

Fig. 3-1 - Continued

Mode: 20 foot container; carry 4 engines per container
Demand = 26 engines per year or 365/26 = break 1 engine every 14 days
Repairables = 26 engines per year
Demand + Repairables = 52 engines transported per year

RHEIN-MAIN

14 days - 18 engines on hand
98 days - 17 engines on hand
85 days - 16 engines on hand
84 days - 15 engines on hand
84 days - 14 engines on hand
Average on hand = 15.65
Decision: Add 3 engines

Criteria:

Average on hand ≥ 14.24
Minimum on hand ≥ 14

# engines on hand	18	17	16	15	14	17	16	15	14	17	16	15	14	17
Day engine arrives						70				126				182
Day engine breaks		14	28	42	56	70	84	98	112	126	140	154	168	182
Day engine ordered		14								126				182
Day engine shipped					56				112				168	
Day in cycle	1	14	28	42	56	70	84	98	112	126	140	154	168	182

Fig. 3-2. Proposed System: Intermodal Surface Transportation

# engines on hand	16	15	14	17	16	15	14	17	16	15	14	17	16
Day engine arrives				238				294				350	
Day engine breaks	196	210	224	238	252	266	280	294	308	322	336	350	364
Day engine ordered				238				294				350	
Day engine shipped			224				280				336		
Day in cycle	196	210	224	238	252	266	280	294	308	322	336	350	364

<u>KELLY</u>

14 days - 57 engines on hand
126 days - 53 engines on hand
225 days - 49 engines on hand
Average on hand = 50.59
Decision: Add 7 engines

Criteria:

Average on hand ≥ 49.24
Minimum on hand ≥ 49

# engines on hand	57	53	49	53	49	53	49	53	49	53	49	53	49
Day engine arrives				112		168		204		250		336	
Day engine shipped		14	70		126		182		238		294		350
Day in cycle	1	14	70	112	126	168	182	204	238	250	294	336	350

Fig. 3-2 - Continued

for the current system, seven additional engines are required at Kelly AFB and three additional engines are required at Rhein-Main AB, Germany, when 20 foot containers and intermodal surface transportation systems are used for C-130-7 engine distribution. When the proposed system employs the use of 40 foot containers and intermodal surface transportation systems, it was determined that seven additional engines are needed at both Kelly AFB and Rhein-Main AB, as depicted in Figure 3-3.

Transportation Costs

The next step in the data analysis involved determination of the annual transportation costs for the air and surface transportation system alternatives over the 15 year period of analysis. Figures 3-4 through 3-7 graphically illustrate the routing networks and transportation rates for the strategies under investigation. The current air transportation system, shown in Figure 3-4, involves airlift of C-130-7 engines between Kelly AFB and Rhein-Main AB, with an intermediate stop at Tinker AFB, Oklahoma. The intermediate stop is necessary to interchange engines between the MAC Tinker-Rhein-Main airlift channel and the Tinker-Kelly LOGAIR channel. Figures 3-5 and 3-6 provide the intermodal surface routing networks and transportation rates for the 20 and 40 foot movement alternatives, respectively. It is noted that New Orleans and Rotterdam were chosen as

Mode: 40 foot container; carry 8 engines per container
Demand = 26 engines per year or 365/26 = break 1 engine every 14 days
Repairables = 26 engines per year
Demand + Repairables = 52 engines transported per year

RHEIN-MAIN

14 days - 22 engines on hand
56 days - 21 engines on hand
43 days - 20 engines on hand
42 days - 19 through 14 engines on hand
Average on hand = 17.81
Decision: Add 7 engines

Criteria:

Average on hand ≥ 14.24
Minimum on hand ≥ 14

# engines on hand	22	21	22	19	18	17	16	15	14	21	20	19	18
Day engine arrives										126			
Day engine breaks		14	28	42	56	70	84	98	112	126	140	154	168
Day engine ordered						70			112				
Day engine shipped													
Day in cycle	1	14	28	42	56	70	84	98	112	126	140	154	168

Fig. 3-3. Proposed System: Intermodal Surface Transportation

# engines on hand	17	16	15	14	21	20	19	18	17	16	15	14
Day engine arrives					238							
Day engine breaks	182	196	210	224	238	252	266	280	294	318	322	336
Day engine ordered	182			224								336
Day engine shipped												
Day in cycle	182	196	210	224	238	252	266	280	294	318	322	336

# engines on hand	21	20
Day engine arrives	350	
Day engine breaks		364
Day engine ordered		
Day engine shipped		
Day in cycle	350	364

Fig. 3-3 - Continued

KELLY

98 days - 57 engines on hand
287 days - 49 engines on hand
Average on hand = 51.15
Decision: Add 7 engines

Criteria:

Average on hand ≥ 49.24
Minimum on hand ≥ 49

# engines on hand	57	57	57	57	57	49	49	49	49	49	49	49	57	49
Day engine arrives													168	
Day engine shipped						70								182
Day in cycle	1	14	28	42	56	70	84	98	112	126	140	154	168	182

# engines on hand	49	49	49	49	49	49	57	49	49	49	49	49	49
Day engine arrives							280						
Day engine shipped													
Day in cycle	196	210	224	238	252	266	280	294	308	322	336	350	364

Fig. 3-3 - Continued

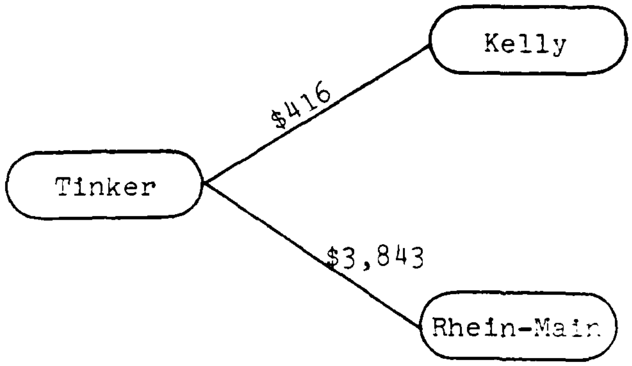

Fig. 3-4. Air Transportation Costs

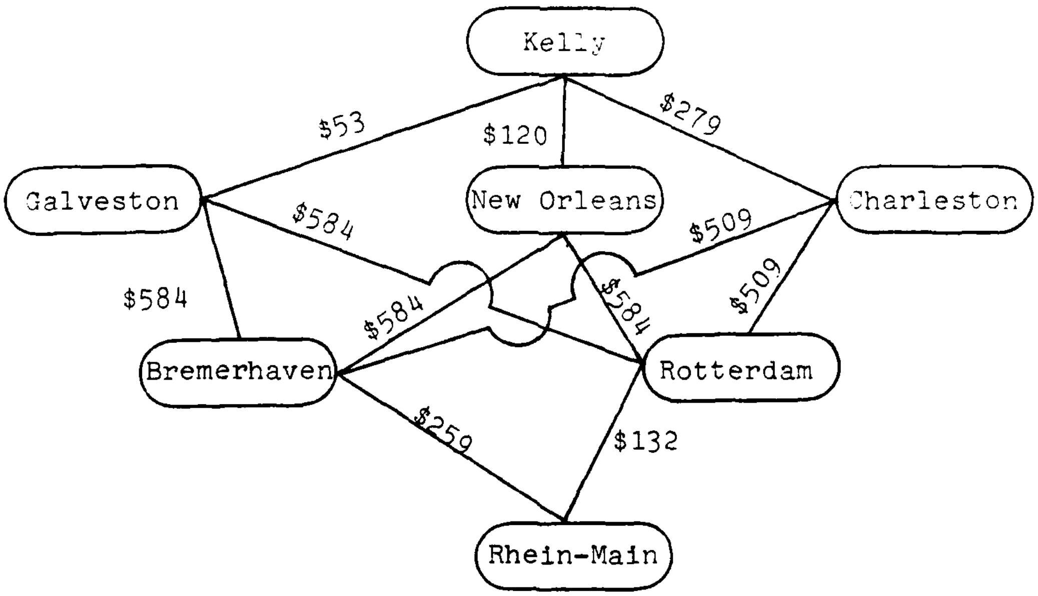

Fig. 3-5. 20' Container Surface Transportation Routes

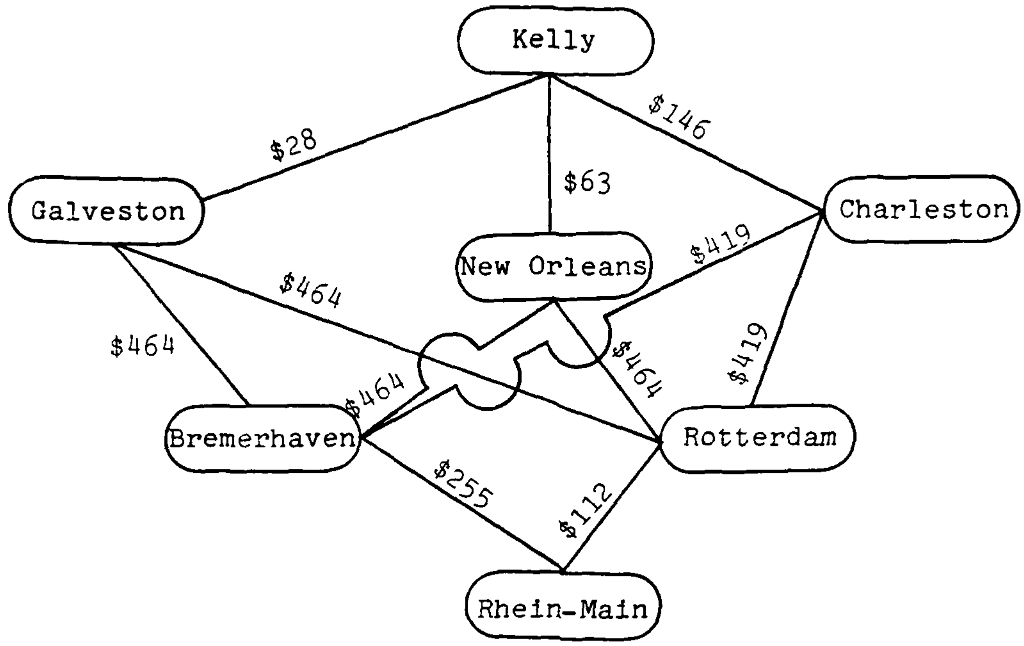

Fig. 3-6. 40' Container Surface Transportation Routes

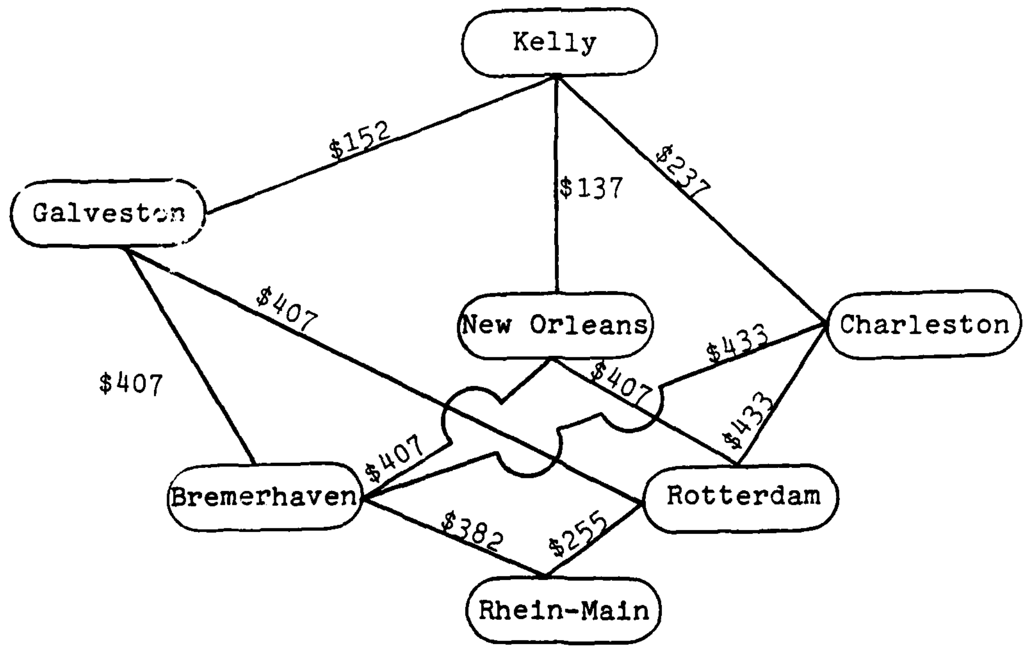

Fig. 3-7. Break-Bulk Surface Routes

the primary seaports of embarkation/debarkation for the proposed system. Figure 3-7 is included to illustrate the break-bulk surface transportation routes and rates which will be discussed in the section on sensitivity analysis.

To determine the annual total transportation costs for the present air transportation system, the costs from each leg of the selected routes were combined and multiplied by 52 engines. The engine demand represented a yearly movement of 26 serviceable engines to Rhein-Main AB and a yearly movement of 26 repairable engines to Kelly AFB. The air transportation costs were then increased by an annual rate of 14 percent for each succeeding year, and then discounted back to 1982 based on end-of-year payments and a 10 percent discount factor. Table 3-2 illustrates the results of the analysis for the air transportation system and shows an estimated 15 year total cost of approximately $3.92 million dollars. Since no additional engines are required for the current air transportation strategy, this figure represents the total distribution costs for the current system.

The computation of transportation costs for the proposed systems involving the use of 20 foot and 40 foot containers was similar to the computation of transportation costs for the current system. That is, the transportation rates for each route segment were combined and multiplied by the yearly engine demand. However, before the annual costs could be discounted, acquisition costs and inventory carrying

TABLE 3-2

AIR TRANSPORTATION SYSTEM: KELLY → TINKER → RHEIN-MAIN

Year	Transportation Total Cost	Discount Factor	Discounted Total Cost	Accumulated Discounted Total Cost
1982	221,468	.9091	201,337	201,337
1983	252,474	.8264	208,644	409,981
1984	287,820	.7513	216,239	626,220
1985	325,115	.6830	224,102	850,322
1986	374,051	.6209	232,248	1,082,570
1987	426,418	.8645	240,713	1,323,283
1988	486,116	.5132	249,475	1,572,758
1989	554,172	.4665	258,521	1,831,279
1990	631,757	.4241	267,928	2,099,207
1991	720,203	.3855	277,638	2,376,845
1992	821,031	.3505	287,771	2,664,616
1993	935,975	.3186	298,202	2,962,818
1994	1,067,012	.2897	309,113	3,271,931
1995	1,216,393	.2633	320,276	3,592,207
1996	1,386,688	.2394	331,973	3,924,180
			3,924,180	

costs had to be computed since the proposed surface intermodal systems involved the addition of engines in order to provide the same level of customer service as the present system.

Acquisition Costs

It was determined that 10 additional engines are needed for the 20 foot container intermodal transportation system, and 14 additional engines are needed for the 40 foot container system. It was assumed that the acquisition would take place in the initial year of the study and that the current engine cost would remain at $91,000. However, since the engine life was assumed to be 20 years and since the study assumed a 15 year time period, each additional engine bought would have a salvage value for the remaining five year useful life. Therefore, the acquisition cost was offset by a salvage value.

To compute the salvage value, the first step involved dividing the engine acquisition cost of $91,000 by 20 years. This produced a yearly straight line depreciation value of $4,550 per engine, assuming a zero salvage value at the end of year 20. Since it was estimated that the C-130 system would be replaced in 15 years, the next step involved multiplying $4,550 times the remaining 5 year useful life. This resulted in a salvage value of $22,500 per engine. The next step involved increasing the salvage value of $22,500 by 8 percent per year for 15 years to account for general price inflation. The resulting annual cost figures were discounted back to 1982 present value terms using a 10 percent discount factor. The entire process then resulted in a salvage value of $15,821 which was deducted from the $91,000 engine acquisition cost to establish a net acquisition cost of $75,179 per engine in 1982.

The net acquisition cost for the 10 engines needed for additional inventory for the 20' container system was then computed as 10 times $75,179, or $751,790. The net acquisition cost for the 14 engines needed for additional inventory for the 40' container system proposal was computed as 14 times $75,179, or $1,052,506. To compute total acquisition costs, a discount factor of 1.00 was applied since it was assumed that the engines would be bought at the beginning of the study.

Inventory Carrying Cost

As explained in the methodology, the inventory carrying cost per engine was computed at 26 percent of the yearly depreciation value, based on a 20 year useful life. The resulting figure was multiplied by 10 or 14 engines, depending on whether the 20 foot or 40 foot container systems was being considered; then increased by 8 percent per year to account for general price inflation; and finally discounted back to 1982 present value terms.

Total Cost Models

The total cost for the current air transportation system, over the 15 year period, was previously reported to be approximately $3.92 million (see Table 3-2). To compute the total accumulated costs for the proposed intermodal surface transportation systems, the acquisition costs and yearly transportation and inventory carrying costs were inflated, discounted, and summed as shown in Tables 3-3 and 3-4. The models indicate that the current air transportation system costs are 136 percent greater than the estimated cost of $1.67 million for the proposed surface transportation system using 20 foot containers, and 113 percent greater than the estimated cost of $1.84 million for the proposed surface transportation system using 40 foot containers. These results will be further analyzed in the next section.

Break-Even Analysis

In observing the total cost Tables 3-2, 3-3 and 3-4, it appears that the total costs for the proposed systems are greater than those of the current system for 1982. However, when a comparison of the total costs of the proposed and present systems is made in year 15 (1996), it is discovered that the proposed systems produce lower costs. Break-even analysis was used for the purpose of establishing the point, or period of time, at which the total costs of the proposed and present systems are equal. This was accomplished by

TABLE 3-3

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: 20 FOOT CONTAINER SYSTEM
ROUTING: KELLY → NEW ORLEANS → ROTTERDAM → RHEIN-MAIN
DEMAND: 52 ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted	Sum of Discounted Annual Cost
1982	751,790			751,790	1.0000	751,790	
1982		43,472	11,830	55,302	.9091	50,275	802,065
1983		49,558	12,776	62,334	.8264	51,513	854,278
1984		56,496	13,799	70,295	.7513	52,813	907,091
1985		64,406	14,902	79,308	.6830	54,167	961,258
1986		73,423	16,095	89,518	.6209	55,582	1,016,840
1987		83,702	17,382	101,084	.5645	57,062	1,073,902
1988		95,420	18,773	114,193	.5132	58,604	1,132,506
1989		108,779	20,225	129,004	.4665	60,180	1,192,686
1990		124,008	21,897	145,905	.4241	61,878	1,254,564
1991		141,369	23,649	165,018	.3855	63,614	1,318,178
1992		161,161	25,541	186,702	.3505	65,439	1,383,617
1993		183,724	27,584	211,308	.3186	67,323	1,450,940
1994		209,445	29,791	234,236	.2897	69,307	1,520,247
1995		238,767	32,174	270,941	.2633	71,339	1,591,586
1996		272,195	34,748	306,943	.2394	73,482	1,665,068
						1,665,068	

TABLE 3-4

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: 40 FOOT CONTAINER SYSTEM
ROUTING: KELLY → NEW ORLEANS → ROTTERDAM → RHEIN-MAIN
DEMAND: 52 ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted	Sum of Discounted Annual Cost
1982	1,052,506			1,052,506	1.000	1,052,506	
1982		33,228	16,562	49,790	.9091	45,264	1,097,770
1983		37,880	17,887	55,767	.8264	46,086	1,143,856
1984		43,183	19,318	62,501	.7513	46,957	1,190,813
1985		49,229	20,863	70,092	.6830	47,873	1,238,686
1986		56,121	22,532	78,653	.6209	48,836	1,287,522
1987		63,978	24,335	88,313	.5645	49,853	1,337,375
1988		72,935	26,282	99,217	.5132	50,918	1,388,293
1989		83,145	28,385	111,530	.4665	52,029	1,440,322
1990		94,786	30,655	125,441	.4241	53,200	1,493,522
1991		108,056	33,108	141,164	.3855	54,419	1,547,941
1992		123,184	35,756	158,940	.3505	55,708	1,603,649
1993		140,429	38,617	179,046	.3186	57,044	1,660,693
1994		160,089	41,706	201,795	.2897	58,460	1,719,153
1995		182,502	45,043	227,545	.2633	59,913	1,779,066
1996		208,052	48,646	256,698	.2394	61,454	1,840,520
						1,840,520	

utilizing a break-even analysis graph projecting the total cost per year of each system over a 15 year time horizon. The break-even point, at which both the present and proposed system's cost curves intersect, indicates the point of equality in total system costs. By drawing a line from the point of intersection perpendicular to the time axis, we can indicate the period of time necessary in recovering the cost from the proposed system which was initially more expensive. Therefore, if operations are to be limited to the left of the break-even point, it would be more economical to keep the current system; however, if operations will fall on the right side of the break-even point, it would be more economical to convert to either of the proposed systems.

In accordance with the guidelines specified in the above context, a break-even analysis graph was constructed to determine the point of intersection between the current system and the proposed 20 foot container system, as shown in Figure 3-8.

By plotting the accumulated costs factors derived from Tables 3-2 and 3-3, the resulting break-even point was estimated to be between the years of 1985 and 1986, or 4.4 years from the proposed system's implementation date. This reflects a considerable amount of cost savings over the current system, when projected out to the 15 year point.

When 40 foot containers are used, the break-even point tends to shift itself to the right due to the higher

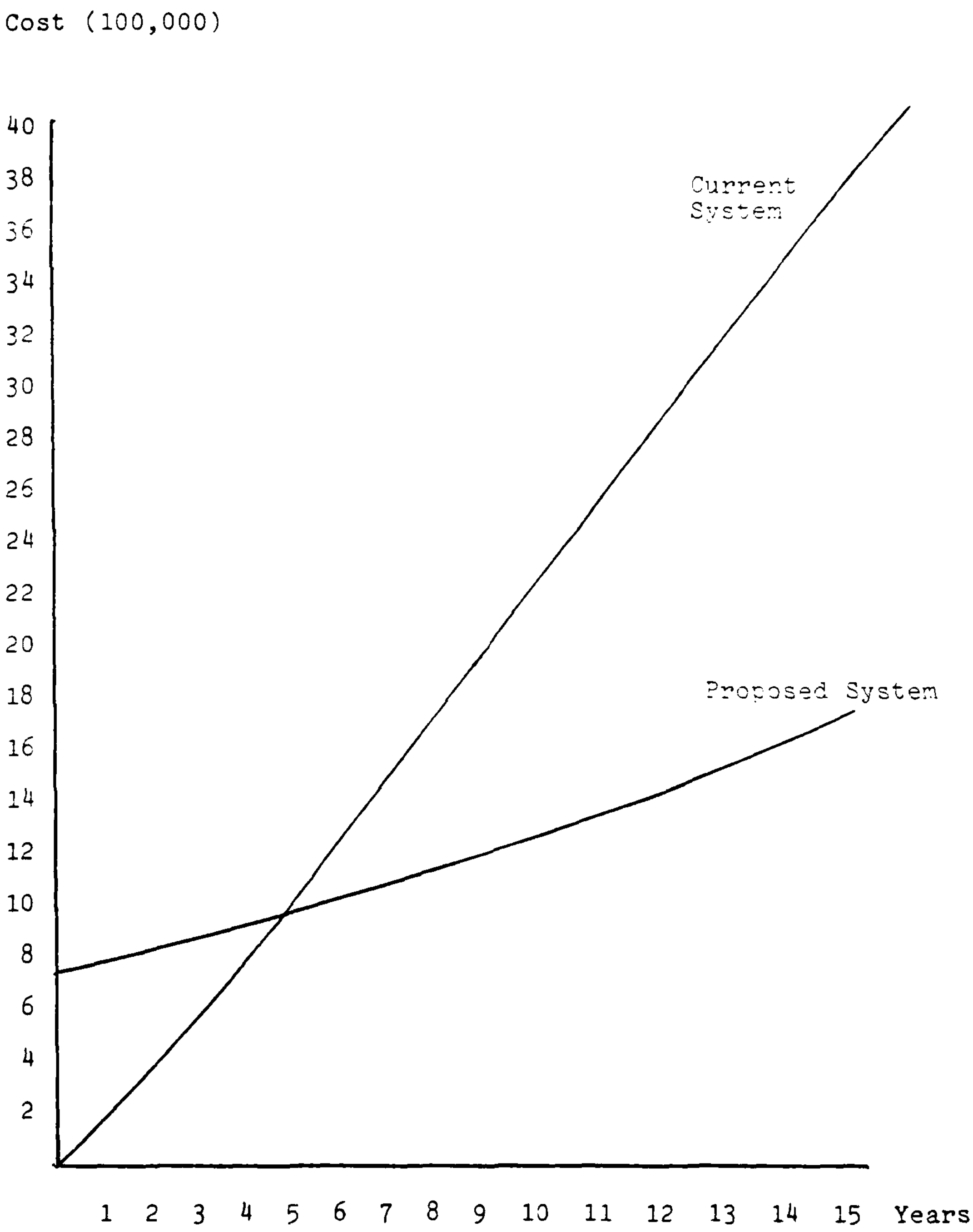

Fig. 3-8. 20' Container and Current System Break-Even Analysis

fixed costs associated with the larger container. This is shown in Figure 3-9, using data derived from Tables 3-2 and 3-4.

Sensitivity Analysis of the Results

An analysis of model sensitivity was performed on four separate parameters used in this study. Specifically, sensitivity analysis involved changing engine demand, the various rates, surface routing and surface transportation modes. Each of these parameters will be discussed, with respect to total costs over the 15 year study period.

Changes in Demand

The expected demand of 26 C-130 engines was varied by a constant figure of plus and minus 10 percent, to determine how the change in demand will effect the system's total cost. The resulting figures were then rounded to the next whole number, indicating an increase of 3 engines at plus 10 percent and a decrease of 2 engines at minus 10 percent (see Figures 3-10 through 3-13). The resulting tabulations are presented in Tables 3-5, 3-6 and 3-7. The tables show that when the expected demand dropped to 24 engines, the current system cost was found to be $2,017,208, or 126 percent greater than the system being proposed using 20 foot containers and $1,916,512, or 112 percent greater than when 40 foot containers are used. By increasing the demand to 29 engines, the resulting current system cost was $2,532,419,

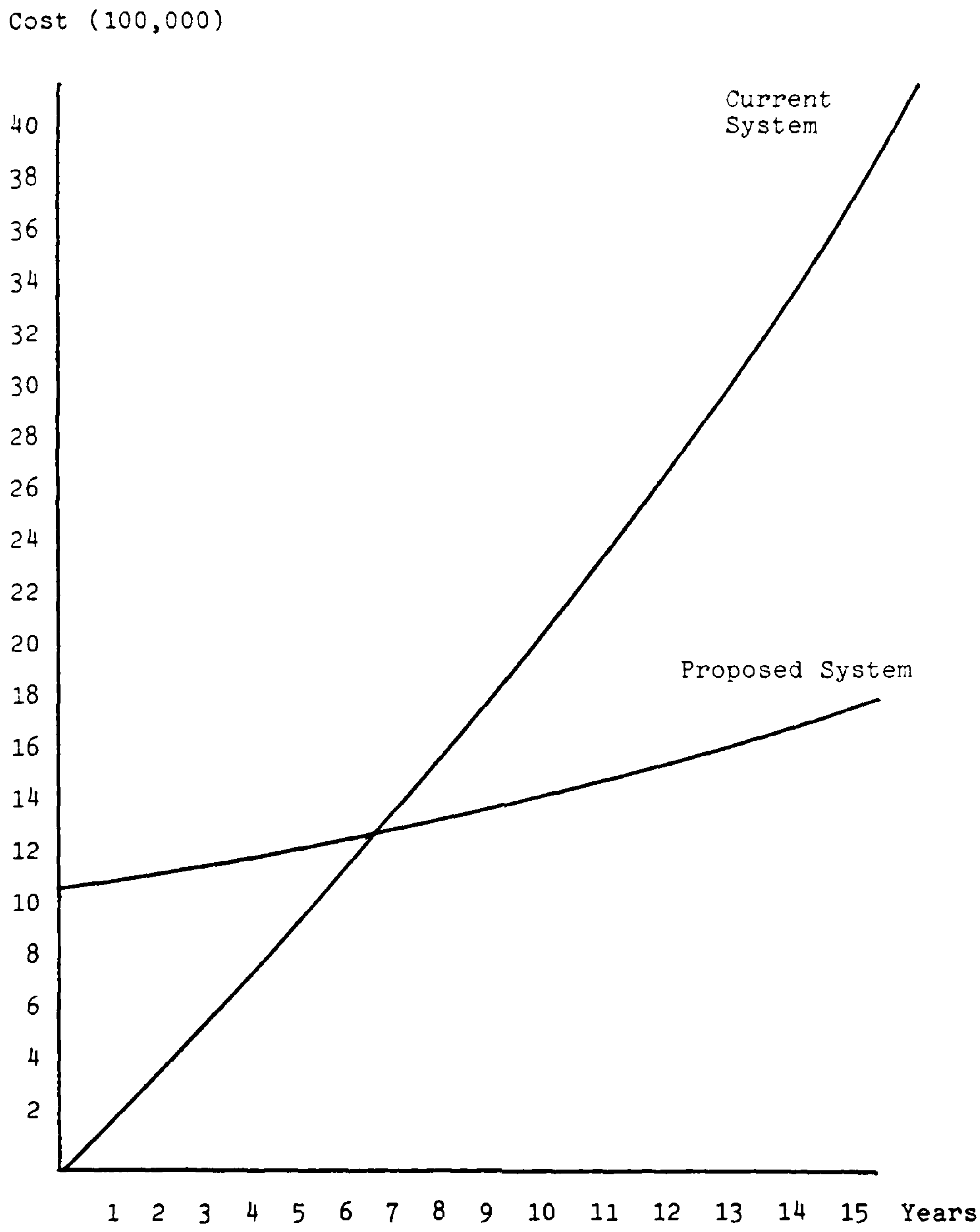

Fig. 3-9. 40' Container and Current System Break-Even Analysis

Mode: 20 foot container; carry 4 engines per container
Demand = 29 engines or 365/29 = break 1 engine every 12 days
Repairable = 29 engines
Demand + Repairable = 58 engines transported per year

RHEIN-MAIN

30 days - 18 engines
95 days - 17 engines
60 days - 14 engines
Average on hand = 15.89
Decision: Add 4 engines

Demand:

26 x 1.10 = 28.6 = 29

# engines on hand	19	18		17	16	15	14		17	16	15	14		17
Day engine arrives								68					116	
Day engine breaks		12		24	36	48	60		72	84	96	108		120
Day engine ordered			18				60					108		
Day engine shipped						48					96			
Day in cycle	1			24		48			72		96			120

Fig. 3-10. Proposed System: Surface Transportation

# engines on hand	16	15	14		17	16	15	14		17	16	15
Day engine arrives				164					212			
Day engine breaks	132	144	156		168	180	192	204		216	228	240
Day engine ordered			156					204				
Day engine shipped		144					192					240
Day in cycle		144			168		192			216		240

# engines on hand	14		17	16	15	14		17	16	15	14		17
Day engine arrives		260					308					356	
Day engine breaks	252		264	276	288	300		312	324	336	348		360
Day engine ordered	252					300					348		
Day engine shipped					288					336			
Day in cycle			264		288			312		336			360

Fig. 3-10 - Continued

KELLY

12 days - 57 engines
72 days - 53 engines
Average on hand = 50.05
Decision: Add 7 engines

# engines on hand	57	53	49	53	49	53	49	53	49	53	49	53
Day engine arrives				104		152		200		248		296
Day engine shipped		12	60		108		156		204		252	
Day in cycle	1	12	60		108		156		204		252	

# engines on hand	49	53	49
Day engine arrives		344	
Day engine shipped	300		348
Day in cycle	300		348

Fig. 3-10 - Continued

Mode: 20 foot container; carry 4 engines per container
Demand = 24 engines or 365/24 = break 1 engine every 15 days
Repairable = 24 engines
Demand + Repairable = 48 engines shipped per year

RHEIN-MAIN

35 days - 18 engines
90 days - 17, 16, 15 engines
60 days - 14 engines
Average on hand = 15.86
Decision: Add 3 engines

Demand:

26 x .9 = 23.4 = 24

# engines on hand	18	17	16	15	14	18	17	16	15	14	18	17	16	15
Day engine arrives						71					131			
Day engine breaks		15	30	45	60		75	90	105	120		135	150	165
Day engine ordered		15					75					135		
Day engine shipped					60					120				
Day in cycle	1	15	30	45	60		75	90	105	120		135	150	165

Fig. 3-11. Proposed System: Surface Transportation

# engines on hand	14	18	17	16	15	14	18	17	16	15	14	18
Day engine arrives		191					251					311
Day engine breaks	180		195	210	225	240		255	270	285	300	
Day engine ordered			195					255				
Day engine shipped	180					240					300	
Day in cycle	180		195	210	225	240		255	270	285	300	

# engines on hand	17	16	15	14
Day engine arrives				
Day engine breaks	315	330	345	360
Day engine ordered	315			
Day engine shipped				360
Day in cycle	315	330	345	360

Fig. 3-11 - Continued

KELLY

15 days - 57 engines
145 days - 53 engines
205 days - 49 engines
Average on hand = 50.92
Decision: Add 7 engines

# engines on hand	57	53	49	53	49	53	49	53	49	53	49	53
Day engine arrives				116		176		236		296		356
Day engine shipped		15	75		135		195		255		315	
Day in cycle	1	15	75	116	135	176	195	236	255	296	315	356

Fig. 3-11 - Continued

Mode: 40 foot container; carry 8 engines per container
Demand = 29 engines or 365/29 = break 1 engine every 12 days
Repairable = 29 engines
Demand + Repairable = 58 engines transported per year

RHEIN-MAIN

12 days - 23 engines
24 days - 22 engines
48 days - 21, 20, 19, 18 engines
41 days - 17 engines
36 days - 16, 15 engines
24 days - 14 engines

Demand:

26 x 1.10 = 28.6 = 29

Average on hand = 18.35
Decision: Add 8 engines

# engines on hand	23	22	21	20	19	18	17	16	15	14	22	21	20
Day engine arrives											116		
Day engine breaks		12	24	36	48	60	72	84	96	108		120	132
Day engine ordered						60							
Day engine shipped									96				
Day in cycle	1	12	24	36	48	60	72	84	96	108		120	132

Fig. 3-12. Proposed System: Surface Transportation

# engines on hand	19	18	17	16	15	14	22	21	20	19	18
Day engine arrives							212				
Day engine breaks	144	156	168	180	192	204		216	228	240	252
Day engine ordered		156									252
Day engine shipped					192						
Day in cycle	144	156	168	180	192	204		216	228	240	252

# engines on hand	17	16	15	14	22	21	20	19	18	17
Day engine arrives					308					
Day engine breaks	264	276	288	300		312	324	336	348	360
Day engine ordered									348	
Day engine shipped			288							
Day in cycle	264	276	288	300		312	324	336	348	360

Fig. 3-12 - Continued

KELLY

72 days - 57 engines
293 days - 49 engines
Average on hand = 50.58
Decision: Add 7 engines

# engines on hand	57	49	57	49	57	49	57	49
Day engine arrives			152		248		344	
Day engine shipped		60		156		252		348
Day in cycle	1	60		156		252		348

Fig. 3-12 - Continued

Mode: 40 foor container; carry 8 engines per container
Demand = 24 engines or 365/24 = break 1 engine every 15 days
Repairable = 24 engines
Demand + Repairable = 48 engines transported per year

RHEIN-MAIN

12 days - 22 engines
50 days - 21 engines
45 days - 20, 19, 18, 17, 16, 15 engines
33 days - 14 engines
Average on hand = 17.81
Decision: Add 6 engines

Demand:
26 x .9 = 23.4 = 24

# engines on hand	21	20	19	18	17	16	15	14	22	21	20	19	18
Day engine arrives									116				
Day engine breaks		15	30	45	60	75	90	105		120	135	150	165
Day engine ordered					60								
Day engine shipped										120			
Day in cycle	1	15	30	45	60	75	90	105		120	135	150	165

Fig. 3-13. Proposed System: Surface Transportation

# engines on hand	17	16	15	14	22	21	20	19	18	17	16	15
Day engine arrives					236							
Day engine breaks	180	195	210	225		240	255	270	285	300	315	330
Day engine ordered	180									300		
Day engine shipped						240						
Day in cycle	180	195	210	225		240	255	270	285	300	315	330

# engines on hand	14	22	21
Day engine arrives		356	
Day engine breaks	345		360
Day engine ordered			
Day engine shipped			360
Day in cycle	345		360

Fig. 3-13 - Continued

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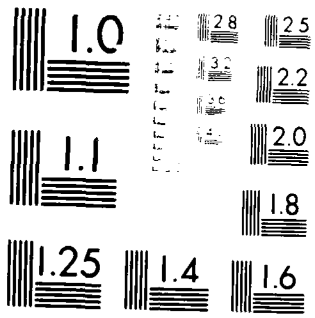

MICROCOPY RESOLUTION TEST CHART

KELLY

68 days - 57 engines
297 days - 49 engines
Average on hand = 50.49
Decision: Add 7 engines

# engines on hand	57	49	57	49	57	49
Day engine arrives			176		296	
Day engine shipped		60		180		300
Day in cycle	1	60		180		300

Fig. 3-13 - Continued

TABLE 3-5

AIR TRANSPORTATION SYSTEM
ROUTING: KELLY → TINKER → RHEIN-MAIN
DEMAND: 48 ENGINES PER YEAR

Year	Transportation Total Cost	Discount Factor	Total Cost Discounted	Accumulated Annual Discounted Total Cost
1982	204,432	.9091	185,149	185,849
1983	233,052	.8264	192,594	378,443
1984	265,680	.7513	199,605	578,048
1985	302,875	.6830	206,864	784,912
1986	345,278	.6209	214,383	999,295
1987	393,616	.5645	222,196	1,221,491
1988	448,723	.5132	230,285	1,451,776
1989	511,544	.4665	238,635	1,690,411
1990	583,160	.4241	247,318	1,937,729
1991	664,802	.3855	256,281	2,194,010
1992	757,875	.3505	265,635	2,459,645
1993	863,977	.3186	275,263	2,734,908
1994	984,934	.2897	285,335	3,020,243
1995	1,122,825	.2633	295,640	3,315,883
1996	1,280,020	.2394	306,437	3,622,320
			3,622,320	

TABLE 3-5 - Continued

DEMAND: 58 ENGINES PER YEAR

Year	Transportation Total Cost	Discount Factor	Total Cost Discounted	Accumulated Annual Discounted Total Cost
1982	247,022	.9091	224,568	224,568
1983	281,605	.8264	232,718	457,286
1984	321,030	.7513	241,190	698,476
1985	365,974	.6830	249,960	948,436
1986	417,210	.6209	259,046	1,207,482
1987	475,620	.5645	268,487	1,475,969
1988	542,207	.5132	278,261	1,754,230
1989	618,115	.4665	288,351	2,042,581
1990	704,652	.4241	298,843	2,431,424
1991	803,303	.3855	309,673	2,651,097
1992	915,765	.3505	320,976	2,972,073
1993	1,043,972	.3186	330,730	3,302,803
1994	1,190,128	.2897	344,780	3,647,583
1995	1,356,746	.2633	357,231	4,004,814
1996	1,546,691	.2394	370,278	4,375,092
			4,375,092	

TABLE 3-6

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: 20 FOOT CONTAINER SYSTEM
ROUTING: KELLY → NEW ORLEANS → ROTTERDAM → RHEIN-MAIN
DEMAND: 48 ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted	Sum of Discounted Annual Cost
1982	751,790			751,790	1.0000	751,790	751,790
1982		40,128	11,830	51,958	.9091	47,235	799,025
1983		45,776	12,776	58,522	.8264	48,363	847,388
1984		52,150	13,799	65,949	.7513	49,547	896,935
1985		59,451	14,902	74,353	.6830	50,783	947,718
1986		67,775	16,095	83,870	.6209	52,075	999,793
1987		77,263	17,382	94,645	.5645	53,427	1,053,220
1988		88,080	18,773	106,853	.5132	54,837	1,108,057
1989		100,411	20,225	120,636	.4665	56,277	1,164,334
1990		114,469	21,897	136,366	.4241	57,833	1,222,167
1991		130,491	23,649	154,140	.3855	59,421	1,281,588
1992		148,763	25,541	174,304	.3505	61,094	1,342,682
1993		169,590	27,584	197,174	.3186	62,820	1,405,502
1994		193,333	29,791	223,124	.2897	64,639	1,470,141
1995		220,399	32,174	252,573	.2633	66,502	1,536,643
1996		251,255	34,748	286,003	.2394	68,469	1,605,112
						1,605,112	

TABLE 3-6 - Continued

DEMAND: 58 ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted	Sum of Discounted Annual Cost
1982	826,969			826,969	1.0000	826,969	826,969
1982		48,488	13,013	61,501	.9091	55,911	882,880
1983		55,276	14,054	69,330	.8264	57,294	940,174
1984		63,015	15,178	78,193	.7513	58,746	998,920
1985		71,837	16,393	88,230	.6830	60,261	1,059,181
1986		81,894	17,704	99,598	.6209	61,840	1,121,021
1987		93,360	19,120	112,480	.5645	63,495	1,184,516
1988		106,430	20,650	127,080	.5132	65,217	1,249,733
1989		121,330	22,302	143,632	.4665	67,004	1,316,737
1990		138,316	24,086	162,402	.4241	68,875	1,385,612
1991		157,680	26,013	183,693	.3855	70,814	1,456,426
1992		179,756	28,094	207,850	.3505	72,851	1,529,277
1993		204,922	30,342	235,264	.3186	74,955	1,604,232
1994		233,611	32,769	266,380	.2897	77,170	1,681,402
1995		266,316	35,390	301,706	.2633	79,439	1,760,841
1996		303,600	38,222	341,822	.2394	81,832	1,842,673
						1,842,673	

TABLE 3-7

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: 40 FOOT CONTAINER SYSTEM
ROUTING: KELLY → NEW ORLEANS → ROTTERDAM → RHEIN-MAIN
DEMAND: 58 ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted	Accumulated Discounted Total Cost
1982	1,127,685			1,127,685	1.000	1,127,685	
1982		37,062	17,745	54,804	.9091	49,822	1,177,507
1983		42,251	19,165	61,416	.8264	50,754	1,228,261
1984		48,166	20,698	68,864	.7513	51,737	1,279,998
1985		54,909	22,354	77,263	.6830	52,770	1,332,768
1986		62,596	24,142	86,738	.6209	53,855	1,386,623
1987		71,360	26,073	97,433	.5645	55,000	1,441,623
1988		81,350	28,159	109,509	.5132	56,200	1,497,823
1989		92,739	30,142	122,881	.4665	57,323	1,555,146
1990		105,723	32,845	138,568	.4241	58,766	1,613,912
1991		120,524	35,472	155,996	.3855	60,136	1,674,048
1992		137,397	38,310	175,707	.3505	61,585	1,735,633
1993		156,633	41,375	198,008	.3186	63,085	1,798,718
1994		178,561	44,685	223,246	.2897	64,674	1,863,392
1995		203,560	48,260	251,820	.2633	66,304	1,929,696
1996		232,058	52,121	284, 179	.2394	68,032	1,997,728
						1,997,728	

TABLE 3-7 - Continued

DEMAND: 48 ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted	Accumulated Discounted Total Cost
1982	977,327			977,327	1.0000	977,327	
1982		30,672	15,379	46,051	.9091	41,864	1,019,191
1983		34,966	16,609	51,575	.8264	42,621	1,061,812
1984		39,861	17,938	57,799	.7513	43,424	1,105,236
1985		45,442	19,373	64,815	.6830	44,268	1,149,504
1986		51.804	20,923	72,727	.6209	45,156	1,194,660
1987		59,056	22,597	81,653	.5645	46,093	1,240,753
1988		67,324	24,405	91,729	.5132	47,075	1,287,828
1989		76,750	26,357	103,107	.4665	48,099	1,335,927
1990		87,495	28,465	115,960	.4241	49,178	1,385,105
1991		99,744	30,743	130,487	.3855	50,302	1,435,407
1992		113,708	33,202	146,910	.3505	51,491	1,486,898
1993		129,627	35,858	165,485	.3186	52,723	1,539,621
1994		147,775	38,727	186,502	.2897	54,029	1,593,650
1995		168,463	41,825	210,288	.2633	55,368	1,649,018
1996		192,048	45,171	237,219	.2394	56,790	1,705,808
						1,705,808	

or 137 percent greater than the proposed system using 20 foot containers and $2,377,364, or 119 percent greater than when 40 foot containers are used.

Changes in Rates

The next step in the sensitivity analysis involved the evaluation of differences in total costs that would occur if the transportation costs were increased to an annual inflation rate of 20 percent as opposed to the estimated 14 percent. Using the estimated 14 percent as a base, the annual inflation rate was also decreased to 8 percent in arriving at the amount of change in total transportation costs. The resulting total costs, as described in Tables 3-8, 3-9 and 3-10, indicated that a 20 percent transportation cost inflation factor would result in a current system cost of $3,890,977, or 189 percent greater than the system being proposed using 20 foot containers and $3,808,693, or 176 percent greater using 40 foot containers. In using an 8 percent inflation factor, the resulting cost of the present system was $1,247,296, or 88 percent greater than the proposed system using 20 foot containers and $1,013,103, or 61 percent greater using 40 foot containers.

Changes in Surface Routing Structure

A total of five additional surface routes were considered. The total costs tabulated for each of the five surface routes were used in comparison with the estimated

TABLE 3-8

AIR TRANSPORTATION SYSTEM
TOTAL COST: 20 PERCENT INCREASE IN TRANSPORTATION RATES
ROUTING: KELLY → TINKER → RHEIN-MAIN
DEMAND: 52 ENGINES PER YEAR

Year	Transportation Total Cost	Discount Factor	Total Cost Discounted	Accumulated Discounted Total Cost
1982	221,468	.9091	201,337	201,337
1983	265,762	.8264	219,626	420,963
1984	318,914	.7513	239,600	660,563
1985	382,969	.6830	261,382	921,945
1986	459,236	.6209	285,140	1,207,085
1987	551,083	.5645	311,086	1,518,171
1988	661,300	.5132	339,379	1,857,550
1989	793,560	.4665	370,196	2,227,746
1990	952,272	.4241	403,859	2,631,605
1991	1,142,726	.3855	440,521	3,072,126
1992	1,371,271	.3505	480,630	3,552,756
1993	1,645,526	.3186	524,265	4,077,021
1994	1,974,631	.2897	572,051	4,649,072
1995	2,369,557	.2633	623,904	5,272,976
1996	2,843,469	.2394	680,726	5,953,702
			5,953,702	

TABLE 3-8 - Continued

TOTAL COST: 8 PERCENT INCREASE IN TRANSPORTATION RATES

Year	Transportation Total Cost	Discount Factor	Total Cost Discounted	Accumulated Discounted Total Cost
1982	221,468	.9091	201,377	201,337
1983	239,185	.8264	197,662	398,999
1984	258,320	.7513	194,076	593,075
1985	278,986	.6830	190,547	783,622
1986	301,305	.6209	187,080	970,702
1987	325,409	.5645	183,973	1,154,675
1988	351,442	.5132	180,360	1,335,035
1989	379,557	.4665	177,063	1,512,098
1990	409,922	.4241	173,840	1,685,938
1991	442,716	.3855	170,667	1,856,605
1992	478,133	.3505	167,586	2,024,191
1993	516,383	.3186	164,520	2,188,711
1994	557,694	.2897	161,564	2,350,275
1995	602,310	.2633	158,588	2,508,863
1996	650,494	.2394	155,728	2,664,591
			2,664,591	

TABLE 3-9

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: 20 FOOT CONTAINER; 20 PERCENT INCREASE IN TRANSPORTATION RATES
ROUTING: KELLY → NEW ORLEANS → ROTTERDAM → RHEIN-MAIN
DEMAND: 52 ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted	Accumulated Discounted Total Cost
1982	751,790			751,788	1.0000	751,790	
1982		43,472	11,830	55,302	.9091	50,275	802,065
1983		52,166	12,776	64,942	.8264	53,668	855,733
1984		62,600	13,799	76,399	.7513	57,397	913,132
1985		75,120	14,902	90,022	.6830	61,485	974,617
1986		90,144	16,095	106,239	.6209	65,964	1,040,311
1987		108,172	17,832	126,004	.5645	71,129	1,111,440
1988		129,807	18,773	148,580	.5132	76,251	1,187,691
1989		155,768	20,225	175,993	.4665	82,101	1,269,792
1990		186,922	21,897	208,819	.4241	88,560	1,358,352
1991		224,306	23,649	247,955	.3855	95,587	1,453,939
1992		269,167	25,541	294,708	.3505	103,295	1,557,234
1993		323,001	27,584	350,585	.3186	111,696	1,668,930
1994		387,601	29,791	417,392	.2879	120,918	1,789,848
1995		465,121	32,174	497,295	.2633	130,938	1,920,786
1996		558,145	34,748	592,893	.2394	141,939	2,062,725
						2,062,725	

TABLE 3-9 - Continued

DEMAND: 8 PERCENT INCREASE IN TRANSPORTATION RATES

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted	Accumulated Discounted Total Cost
1982	751,790			751,790	1.0000	751,790	
1982		43,472	11,830	55,302	.9091	50,275	802,065
1983		46,950	12,776	59,726	.8264	49,358	851,423
1984		50,706	13,799	64,505	.7513	48,463	899,886
1985		54,762	14,902	69,664	.6830	47,581	947,467
1986		59,143	16,095	75,238	.6209	46,715	994,182
1987		63,875	17,832	81,707	.5645	46,124	1,040,306
1988		68,985	18,773	87,758	.5132	45,037	1,085,343
1989		74,503	20,225	94,728	.4665	44,162	1,129,505
1990		80,464	21,897	102,361	.4241	43,411	1,172,916
1991		86,901	23,649	110,550	.3855	42,617	1,215,533
1992		93,853	25,541	119,394	.3505	41,848	1,257,381
1993		101,361	27,584	128,945	.3186	41,082	1,298,463
1994		109,470	29,791	139,261	.2897	40,344	1,338,807
1995		118,227	32,174	150,401	.2633	39,601	1,378,408
1996		127,686	34,748	162,434	.2394	38,887	1,417,295
						1,417,295	

TABLE 3-10

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: 40 FOOT CONTAINER; 20 PERCENT INCREASE IN TRANSPORTATION RATES
ROUTING: KELLY → NEW ORLEANS → ROTTERDAM → RHEIN-MAIN
DEMAND: 52 ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted	Accumulated Discounted Total Cost
1982	1,052,506			1,052,506	1.0000	1,052,506	
1982		33,228	16,562	49,790	.9091	45,264	1,097,770
1983		39,874	17,887	57,761	.8264	47,733	1,145,503
1984		47,848	19,318	67,166	.7513	50,461	1,195,964
1985		57,418	20,863	78,281	.6830	53,465	1,249,429
1986		68,902	22,532	91,434	.6209	56,771	1,306,200
1987		82,682	24,335	107,017	.5645	60,411	1,366,611
1988		99,218	26,282	125,500	.5132	64,406	1,431,017
1989		119,062	28,385	147,447	.4665	68,784	1,499,801
1990		142,874	30,655	173,529	.4241	73,593	1,573,394
1991		171,449	33,108	204,557	.3855	78,856	1,652,250
1992		205,739	35,756	241,495	.3505	84,643	1,736,893
1993		246,887	38,617	285,504	.3186	90,961	1,827,854
1994		296,265	41,706	337,971	.2897	97,910	1,925,764
1995		355,517	45,043	400,560	.2633	105,467	2,031,231
1996		426,621	48,646	475,267	.2394	113,778	2,145,009
						2,145,009	

TABLE 3-10 - Continued

TOTAL COST: 8 PERCENT INCREASE IN TRANSPORTATION RATES

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted	Accumulated Discounted Total Cost
1982	1,052,506			1,052,506	1.0000	1,052,506	
1982		33,228	16,562	49,790	.9091	45,264	1,097,770
1983		35,886	17,887	53,773	.8264	44,438	1,142,208
1984		38,757	19,318	58,075	.7513	43,631	1,185,839
1985		41,858	20,863	62,721	.6830	42,838	1,228,677
1986		45,206	22,532	67,738	.6209	42,058	1,270,735
1987		48,823	24,335	73,158	.5645	41,297	1,312,032
1988		52,729	26,282	79,011	.5132	40,548	1,352,580
1989		56,947	28,385	85,332	.4665	39,807	1,392,387
1990		61,503	30,655	92,158	.4241	39,084	1,431,471
1991		66,423	33,108	99,531	.3855	38,369	1,469,840
1992		71,737	35,756	107,493	.3505	37,676	1,507,516
1993		77,476	38,617	116,093	.3186	36,987	1,544,503
1994		83,674	41,706	125,380	.2897	36,322	1,580,825
1995		90,368	45,043	135,411	.2633	35,653	1,616,478
1996		97,597	48,646	146,243	.2394	35,010	1,651,488
						1,651,488	

total cost of the airlift route structure, in the following manner.

1. Kelly-Galveston-Rotterdam-Rhein-Main

As presented in Table 3-11, the resulting cost using the current route structure was calculated to be $2,321,549 or 145 percent greater than the proposed route using 20 foot containers and $2,116,525 or 117 percent greater than when 40 foot containers are used.

2. Kelly-Charleston-Rotterdam-Rhein-Main

Table 3-12 shows that the total cost of the current route would be $2,183,572 or 125 percent more than the proposed route when 20 foot containers are used and $2,116,525 or 117 percent greater than when the use of 40 foot containers is considered.

3. Kelly-New Orleans-Bremerhaven-Rhein-Main

Resulting costs of the airlift route structure were calculated to be $2,142,796 or 120 percent more than the proposed route using 20 foot containers and $1,951,921 or 99 percent greater using 40 foot containers, as depicted in Table 3-13.

4. Kelly-Charleston-Bremerhaven-Rhein-Main

Table 3-14 describes the resulting costs associated with this routing structure. It shows that the engine shipment costs, using the current route, would be $2,065,402 or 111 percent greater than the proposed system when using 20 foot containers. If 40 foot containers are used for

TABLE 3-11

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: 20 FOOT CONTAINER
ROUTING: KELLY → GALVESTON → ROTTERDAM → RHEIN-MAIN
DEMAND: 52 ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	751,790			751,790	1.0000	751,790
1982		39,988	11,830	51,818	.9091	47,108
1983		45,586	12,776	58,362	.8264	48,230
1984		51,968	13,799	65,767	.7513	49,411
1985		59,244	14,902	74,146	.6830	50,642
1986		67,538	16,095	83,633	.6209	51,928
1987		76,993	17,382	94,375	.5645	53,275
1988		87,773	18,773	106,546	.5132	54,679
1989		100,061	20,225	120,286	.4665	56,113
1990		114,069	21,897	135,966	.4241	57,663
1991		130,039	23,649	553,688	.3855	59,247
1992		148,244	25,541	173,785	.3505	60,912
1993		168,999	27,584	196,583	.3186	62,631
1994		192,658	29,791	222,449	.2897	64,443
1995		219,631	32,174	251,805	.2633	66,300
1996		250,379	34,748	285,127	.2394	68,259
						1,602,631

TABLE 3-11 - Continued

TOTAL COST: 40 FOOT CONTAINER

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	1,052,506			1,052,506	1.0000	1,052,506
1982		31,408	16,562	47,970	.9091	43,610
1983		35,085	17,887	52,972	.8264	43,776
1984		40,818	19,318	60,136	.7513	45,180
1985		46,532	20,863	67,395	.6830	46,031
1986		53,047	22,532	75,579	.6209	46,927
1987		60,473	24,335	84,808	.5645	47,874
1988		68,940	26,282	95,222	.5132	48,868
1989		78,591	28,385	106,976	.4665	49,904
1990		89,549	30,655	120,204	.4241	50,979
1991		102,137	33,108	135,245	.3855	52,137
1992		116,436	35,756	152,192	.3505	53,343
1993		132,738	38,617	171,355	.3186	54,594
1994		151,321	41,706	193,027	.2897	55,920
1995		172,506	45,043	217,549	.2633	57,281
1996		196,656	48,646	245,302	.2394	58,725
						1,807,655

TABLE 3-12

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: 20 FOOT CONTAINER
ROUTING: KELLY → CHARLESTON → ROTTERDAM → RHEIN-MAIN
DEMAND: 52 ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	751,790			751,790	1.0000	751,790
1982		47,840	11,830	59,670	.9091	54,246
1983		54,538	12,776	67,314	.8264	55,628
1984		62,173	13,799	75,972	.7513	57,078
1985		70,877	14,902	85,779	.6830	58,587
1986		80,800	16,095	96,895	.6209	59,009
1987		92,112	17,382	109,494	.5645	61,809
1988		105,007	18,773	123,780	.5132	63,524
1989		119,709	20,225	139,924	.4665	65,279
1990		136,468	21,897	158,365	.4241	67,163
1991		155,573	23,649	179,222	.3855	69,090
1992		177,353	25,541	202,894	.3505	71,114
1993		202,183	27,584	229,767	.3186	73,204
1994		230,484	29,791	260,280	.2897	75,403
1995		262,757	32,174	294,931	.2633	77,655
1996		299,543	34,748	334,291	.2394	80,029
						1,740,608

TABLE 3-12 - Continued

TOTAL COST: 40 FOOT CONTAINER

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	1,052,506			1,052,506	1.0000	1,052,506
1982		35,204	16,562	51,766	.9091	47,060
1983		40,133	17,887	58,020	.8264	47,948
1984		45,751	19,318	65,069	.7513	48,886
1985		52,156	20,863	73,019	.6830	49,872
1986		59,458	22,532	81,990	.6209	50,908
1987		67,782	24,335	92,117	.5645	52,000
1988		77,272	26,282	103,554	.5132	53,144
1989		88,090	28,385	116,475	.4665	54,336
1990		100,422	30,655	131,077	.4241	55,590
1991		114,482	33,108	147,590	.3855	56,896
1992		130,509	35,756	166,265	.3505	58,276
1993		148,780	38,617	187,397	.3186	59,705
1994		169,610	41,706	211,316	.2897	61,218
1995		193,355	45,043	238,398	.2633	62,770
1996		220,425	48,646	269,071	.2394	64,416
						1,875,531

TABLE 3-13

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: 20 FOOT CONTAINER
ROUTING: KELLY → NEW ORLEANS → BREMERHAVEN → RHEIN-MAIN
DEMAND: 52 ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	751,790			751,790	1.0000	751,790
1982		50,076	11,830	61,906	.9091	56,279
1983		57,087	12,776	69,863	.8264	57,735
1984		65,079	13,799	78,878	.7513	59,261
1985		74,190	14,902	89,902	.6830	60,850
1986		84,576	16,095	100,671	.6209	62,507
1987		96,417	17,382	113,799	.5645	64,240
1988		109,915	18,773	128,688	.5132	66,043
1989		125,304	20,225	145,529	.4665	67,889
1990		142,846	21,897	164,743	.4241	69,868
1991		162,845	23,649	186,494	.3855	71,893
1992		185,643	25,541	211,184	.3505	74,020
1993		211,633	27,584	293,217	.3186	76,215
1994		241,262	29,791	271,053	.2897	78,524
1995		275,038	32,174	307,212	.2633	80,889
1996		313,544	34,748	348,292	.2394	83,381
						1,781,384

TABLE 3-13 - Continued

TOTAL COST: 40 FOOT CONTAINER

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	1,052,506			1,052,506	1.0000	1,052,506
1982		40,664	16,562	57,226	.9091	52,024
1983		46,357	17,887	64,244	.8264	53,091
1984		52,357	19,318	72,165	.7513	54,218
1985		60,246	20,863	81,109	.6830	55,379
1986		68,680	22,532	91,212	.6209	56,634
1987		78,295	24,335	102,630	.5645	57,935
1988		89,256	26,282	115,538	.5132	59,294
1989		101,752	28,385	130,137	.4665	60,709
1990		115,998	30,655	146,653	.4241	62,196
1991		132,238	33,108	165,346	.3855	63,741
1992		150,750	35,756	186,506	.3505	65,370
1993		171,856	38,617	210,473	.3186	67,057
1994		195,915	41,706	237,621	.2897	68,839
1995		223,343	45,043	268,386	.2633	70,666
1996		254,611	48,646	303,257	.2394	72,600
						1,972,259

TABLE 3-14

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: 20 FOOT CONTAINER
ROUTING: KELLY → CHARLESTON → BREMERHAVEN → RHEIN-MAIN
DEMAND: 52 ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	751,790			751,790	1.0000	751,790
1982		54,444	11,830	66,274	.9091	60,250
1983		62,066	12,776	74,842	.8264	61,849
1984		70,755	13,799	84,554	.7513	63,525
1985		80,661	14,902	95,563	.6830	65,270
1986		91,954	16,095	108,049	.6209	67,088
1987		104,827	17,382	122,209	.5645	68,987
1988		119,503	18,773	138,276	.5132	70,963
1989		136,234	20,225	156,459	.4665	72,988
1990		155,306	21,897	177,203	.4241	75,152
1991		177,049	23,649	200,698	.3855	77,369
1992		201,836	25,541	227,377	.3505	79,696
1993		230,093	27,584	257,677	.3186	82,096
1994		262,306	29,791	292,097	.2897	84,621
1995		299,029	32,174	331,203	.2633	87,206
1996		340,893	34,748	375,641	.2394	89,928
						1,858,778

TABLE 3-14 - Continued

TOTAL COST: 40 FOOT CONTAINER

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	1,052,506			1,052,506	1.0000	1,052,506
1982		42,640	16,562	59,202	.9091	53,821
1983		48,610	17,887	66,497	.8264	54,953
1984		55,415	19,318	74,733	.7513	56,147
1985		63,173	20,863	84,036	.6830	57,397
1986		72,017	22,532	94,549	.6209	58,705
1987		82,100	24,335	106,435	.5645	60,083
1988		93,549	26,282	119,831	.5132	61,497
1989		106,697	28,385	135,082	.4665	63,016
1990		121,634	30,655	152,289	.4241	64,586
1991		138,663	33,108	171,771	.3855	66,218
1992		158,076	35,756	193,832	.3505	67,938
1993		180,207	38,617	218,824	.3186	69,717
1994		205,435	41,706	247,141	.2897	71,597
1995		234,195	45,043	279,238	.2633	73,523
1996		166,984	48,646	315,630	.2394	75,562
						2,007,266

shipments over the same route, a cost of $1,916,914 would be incurred or 95 percent greater than the proposed system.

5. Kelly-Galveston-Bremerhaven-Rhein-Main

The results in Table 3-15 show that the cost for shipment over the current route would be $2,204,508 or 128 percent more than the proposed route using 20 foot cargo containers and $1,984,151 or 102 percent more than when 40 foot containers are used.

Break-Bulk Surface Movement

An evaluation of the costs associated with break-bulk versus containerization was also accomplished. These costs were computed using the six previously discussed surface routes examined in this study. Figure 3-14 shows the requirement for additional engines. Tables 3-16 through 3-18 show calculations of total break-bulk costs for each route. Table 3-19 indicates that break-bulk is cheaper than 20 or 40 foot container systems. These results will be discussed further in the summary and in Chapter IV.

Summary of Results

The final results obtained from this study clearly indicate that the new systems being proposed will be more cost effective than the current system now being used. Even with the acquisition of the additional C-130-7 engines to maintain a satisfactory level of customer service, the proposed intermodal surface transportation systems will yield a

TABLE 3-15

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: [illegible] FOOT CONTAINER
ROUTING: KELLY → GALVESTON → BREMERHAVEN → RHEIN-MAIN
DEMAND: [illegible] ENGINES PER YEAR

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	751,790			751,790	1.0000	751,790
1982		46,592	11,830	58,422	.9091	53,111
1983		53,115	12,776	65,891	.8264	54,453
1984		60,551	13,799	74,350	.7513	55,859
1985		69,028	14,902	83,930	.6830	57,324
1986		78,692	16,095	94,787	.6209	58,853
1987		89,709	17,382	107,091	.5645	60,453
1988		102,268	18,773	121,041	.5132	62,118
1989		116,586	20,225	136,861	.4665	63,846
1990		132,908	21,897	154,805	.4241	65,563
1991		151,515	23,649	175,164	.3855	67,526
1992		172,727	25,541	198,268	.3505	69,493
1993		196,909	27,584	224,493	.3186	71,523
1994		224,476	29,791	254,267	.2897	73,661
1995		255,902	32,174	288,076	.2633	75,850
1996		291,729	34,748	326,477	.2394	78,159
						1,719,672

TABLE 3-15 - Continued

TOTAL COST: 40 FOOT CONTAINER

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	1,052,506			1,052,506	1.0000	1,052,506
1982		38,844	16,562	55,406	.9091	50,370
1983		44,282	17,887	62,169	.8264	51,376
1984		50,482	19,318	69,800	.7513	52,441
1985		57,549	20,863	78,412	.6830	53,555
1986		65,606	22,532	88,138	.6209	54,725
1987		74,791	24,335	99,126	.5645	55,957
1988		85,262	26,282	111,544	.5132	57,244
1989		97,199	28,385	125,584	.4665	58,585
1990		110,806	30,655	141,461	.4241	59,994
1991		126,319	33,108	159,427	.3855	61,459
1992		144,003	35,756	179,759	.3505	63,006
1993		164,164	38,617	202,781	.3186	64,606
1994		187,147	41,706	228,853	.2897	66,299
1995		213,347	45,043	258,390	.2633	68,034
1996		243,216	48,646	291,862	.2394	69,872
						1,940,029

Mode: Break Bulk
Demand = 26 engines or 365/26 = break 1 engine every 14 days
Repairables = 26 engines
Demand + Repairables = 52 engines shipped per year

RHEIN-MAIN

14 days - 18, 17, 16, 15 engines
309 days - 14 engines
Average on hand = 14.38
Decision: Add 4 engines

# engines on hand	18	17	16	15	14	14	14	14	14	14	14	14	14	14
Day engine arrives						70	84	98	112	126	140	154	168	182
Day engine breaks		14	28	42	56	70	84	98	112	126	140	154	168	182
Day engine ordered		14	28	42	56	70	84	98	112	126	140	154	168	182
Day engine shipped		14	28	42	56	70	84	98	112	126	140	154	168	182
Days in cycle	1	14	28	42	56	70	84	98	112	126	140	154	168	182

# engines on hand	14	14	14	14	14	14	14	14	14	14	14	14	14
Day engine arrives	196	210	224	238	252	266	280	294	308	322	336	350	364
Day engine breaks	196	210	224	238	252	266	280	294	308	322	336	350	364
Day engine ordered	196	210	224	238	252	266	280	294	308	322	336	350	364
Day engine shipped	196	210	224	238	252	266	280	294	308	322	336	350	364
Days in cycle	196	210	224	238	252	266	280	294	308	322	336	350	364

Fig. 3-14. Proposed System: Surface Transportation System (Break-Bulk)

KELLY

14 days - 54, 53, 52, 51, 50 engines
309 days - 49 engines
Average on hand = 51.45
Decision: Add 4 engines

# engines on hand	54	53	52	51	5C	49	49	49	49	49	49	49	49	49
Day engine arrives						70	84	98	112	126	140	154	168	182
Day engine shipped		14	28	42	56	70	84	98	112	126	140	154	168	182
Day in cycle	1	14	28	42	56	70	84	98	112	126	140	154	168	182

# engines on hand	49	49	49	49	49	49	49	49	49	49	49	49	49
Day engine arrives	196	210	224	238	252	266	280	294	308	322	336	350	364
Day engine shipped	196	210	224	238	252	266	280	294	308	322	336	350	364
Day in cycle	196	210	224	238	252	266	280	294	308	322	336	350	364

Fig. 3-14 - Continued

TABLE 3-16

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: BREAK BULK
ROUTING: KELLY → GALVESTON → BREMERHAVEN → RHEIN-MAIN

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	601,432			601,432	1.0000	601,432
1982		48,932	9,464	58,396	.9091	53,088
1983		55,782	10,221	66,003	.8264	54,545
1984		63,591	11,039	74,630	.7513	56,070
1985		72,494	11,922	84,416	.6830	57,656
1986		82,643	12,876	95,519	.6209	59,308
1987		94,214	13,906	108,120	.5645	61,034
1988		107,403	15,018	122,421	.5132	62,826
1989		122,440	16,220	138,660	.4665	64,685
1990		139,582	17,517	157,099	.4241	66,626
1991		159,123	18,919	178,042	.3855	68,635
1992		181,400	20,432	201,832	.3505	70,742
1993		206,796	22,067	228,863	.3186	72,916
1994		235,748	23,832	259,580	.2897	75,200
1995		268,752	25,739	294,491	.2633	77,539
1996		306,378	27,798	334,176	.2394	80,002
						1,582,304

TABLE 3-16 - Continued

ROUTING: KELLY → GALVESTON → ROTTERDAM → RHEIN-MAIN

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	601,432			601,432	1.0000	601,432
1982		42,328	9,464	51,792	.9091	47,084
1983		48,254	10,221	58,475	.8264	48,324
1984		55,009	11,039	66,048	.7513	49,622
1985		62,711	11,922	74,633	.6830	50,974
1986		71,490	12,876	84,366	.6209	52,383
1987		81,499	13,906	95,405	.5645	53,856
1988		92,909	15,018	107,927	.5132	55,388
1989		105,916	16,220	122,136	.4665	56,976
1990		120,744	17,517	138,261	.4241	58,636
1991		137,648	18,919	156,567	.3855	60,357
1992		156,919	20,432	177,351	.3505	62,162
1993		178,888	22,067	200,955	.3186	64,024
1994		203,932	23,832	227,764	.2897	65,983
1995		232,483	25,739	258,222	.2633	67,990
1996		265,030	27,798	292,828	.2394	70,103
						1,465,294

TABLE 3-17

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: BREAK BULK
ROUTING: KELLY → NEW ORLEANS → BREMERHAVEN → RHEIN-MAIN

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	601,432			601,432	1.0000	601,432
1982		48,152	9,464	57,616	.9091	52,379
1983		54,893	10,221	65,114	.8264	53,810
1984		62,578	11,039	73,617	.7513	55,308
1985		71,339	11,902	83,241	.6830	56,853
1986		81,327	12,876	94,203	.6209	58,490
1987		92,713	13,906	106,619	.5645	60,186
1988		105,692	15,018	120,710	.5132	61,948
1989		120,489	16,220	136,709	.4665	63,774
1990		137,357	17,517	154,874	.4241	65,682
1991		156,588	18,919	175,507	.3855	67,657
1992		178,510	20,432	198,942	.3505	69,729
1993		203,501	22,067	225,568	.3186	71,865
1994		231,991	23,832	255,823	.2897	74,111
1995		264,470	25,739	290,209	.2633	76,412
1996		301,496	27,798	329,294	.2394	78,832
						1,568,468

TABLE 3-17 - Continued

ROUTING: KELLY → NEW ORLEANS → ROTTERDAM → RHEIN-MAIN

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	601,432			601,432	1.0000	601,432
1982		41,548	9,464	51,012	.9091	46,375
1983		47,365	10,221	57,586	.8264	47,589
1984		53,996	11,039	65,035	.7513	48,860
1985		61,555	11,902	73,457	.6830	50,171
1986		70,173	12,876	83,049	.6209	51,565
1987		79,997	13,906	93,903	.5645	53,008
1988		91,197	15,018	106,215	.5132	54,509
1989		103,964	16,220	120,184	.4665	56,065
1990		118,519	17,517	136,036	.4241	57,692
1991		135,112	18,919	154,031	.3855	59,378
1992		154,028	20,432	174,460	.3505	61,148
1993		175,591	22,067	197,658	.3186	62,973
1994		200,174	23,832	224,006	.2897	64,894
1995		228,199	25,739	253,938	.2633	66,861
1996		160,147	27,798	287,945	.2394	68,934
						1,451,454

TABLE 3-18

SURFACE TRANSPORTATION SYSTEM
TOTAL COST: BREAK BULK
ROUTING: KELLY → CHARLESTON → ROTTERDAM → RHEIN-MAIN

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	601,432			601,432	1.0000	601,432
1982		48,100	9,464	57,564	.9091	52,331
1983		54,834	10,221	65,055	.8264	53,761
1984		62,511	11,039	73,550	.7513	55,258
1985		71,262	11,902	83,164	.6830	56,801
1986		81,239	12,876	94,115	.6209	58,436
1987		92,612	13,906	106,510	.5645	60,129
1988		105,578	15,018	120,596	.5132	61,889
1989		120,359	16,220	136,579	.4665	63,714
1990		137,209	17,517	154,726	.4241	65,619
1991		156,419	18,919	175,338	.3855	67,592
1992		178,317	20,432	198,749	.3505	69,661
1993		203,282	22,067	225,349	.3186	71,796
1994		231,741	23,832	255,573	.2897	74,039
1995		264,185	25,739	289,924	.2633	76,336
1996		301,171	27,798	328,969	.2394	78,755
						1,567,549

TABLE 3-18 - Continued

ROUTING: KELLY → CHARLESTON → BREMERHAVEN → RHEIN-MAIN

Year	Acquisition Cost Less Salvage	Transportation Cost	Carrying Cost	Total Cost Undiscounted	Discount Factor	Total Cost Discounted
1982	601,432			601,431	1.0000	601,432
1982		54,704	9,464	64,168	.9091	58,335
1983		62,363	10,221	72,584	.8264	59,983
1984		71,093	11,039	82,132	.7513	61,705
1985		81,046	11,902	92,948	.6803	63,232
1986		92,393	12,876	105,269	.6209	65,361
1987		105,328	13,906	119,234	.5645	67,307
1988		120,074	15,018	135,092	.5132	69,329
1989		136,884	16,220	153,104	.4665	71,423
1990		156,048	17,517	173,565	.4241	73,608
1991		177,895	18,919	196,814	.3855	75,871
1992		202,800	20,432	223,232	.3505	78,242
1993		231,192	22,067	253,259	.3186	80,688
1994		263,559	23,832	287,391	.2897	83,257
1995		300,457	25,739	326,196	.2633	85,887
1996		342,521	27,798	370,319	.2394	88,654
						1,684,314

TABLE 3-19

BREAK BULK VS CONTAINERS

Route*	Break Bulk	20' Containers	% Difference	40' Containers	% Difference
1	1,582,304	1,719,672	9	1,940,029	23
2	1,465,294	1,602,631	9	1,807,655	23
3	1,568,468	1,781,384	14	1,972,259	26
4	1,451,454	1,665,068	15	1,840,520	27
5	1,684,314	1,858,778	10	2,007,266	19
6	1,567,549	1,740,608	11	1,875,531	20

* Note,

Route #1 - Kelly-Galveston-Bremerhaven-Rhein-Main

Route #2 - Kelly-Galveston-Rotterdam-Rhein-Main

Route #3 - Kelly-New Orleans-Bremerhaven-Rhein-Main

Route #4 - Kelly-New Orleans-Rotterdam-Rhein-Main

Route #5 - Kelly-Charleston-Bremerhaven-Rhein-Main

Route #6 - Kelly-Charleston-Rotterdam-Rhein-Main cost savings of 136 percent with 20 foot containers and 113 percent using 40 foot containers. The break-even analysis indicated that the cumulative costs of the proposed intermodal surface transportation systems would be less than the current air transportation system in 4.4 years, using 20 foot containers, and in 6.1 years using 40 foot containers.

Sensitivity analysis was performed in order to analyze the effects of changing the transportation rate inflation factor used in calculating the transportation costs of the current and proposed systems. When an equal increase in the inflation rate percentage was applied, the cost savings of the proposed systems appeared to be greater than the base 14 percent inflation factor. In this case, a 20 percent increase in transportation rates was used. When the transportation rates were reduced to an inflation factor of 8 percent, the savings appeared to be minimized.

When the surface routing structure was varied, the total transportation costs of the intermodal systems changed. However, in each of the six routes evaluated, the surface transportation systems produced a considerable cost savings over the currently used air routing structure.

Changes in demand also resulted in a positive relationship to savings. A comparison between break-bulk and containerized shipment, using surface modes, showed that break-bulk shipments were more economical than containerization. However, break-bulk shipment will not be recommended for reasons which will be discussed in Chapter IV.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

Introduction

Table 4-1 was developed to illustrate the total cost of the system now being used for the shipment of C-130-7 engines from Kelly AFB, Texas, to Rhein-Main AB, Germany. It also presents cost comparisons between the currently used system and the proposed systems that involve the use of 20 foot or 40 foot containers. These results clearly show that by implementing either of the proposed systems in 1982, total costs would be less relative to the current system. In addition, the proposed systems include an increase in inventory stock levels which would allow for readily available assets in response to a contingency or major exercise. In acquiring the specified number of additional engines, the initial cost outlay will be recovered by the fifth or seventh year, as determined by the use of break-even analysis. Any period thereafter will produce additional savings.

Concerning the subject of break-bulk shipments, the authors strongly feel that the non-economic advantages realized by the use of container systems far outweigh the cost advantage of break-bulk shippi found in this research.

Containers are widely used in contrast to break-bulk

TABLE 4-1

SUMMARY OF TOTAL COST BY SYSTEM

Air

	(Non-containerized)
Initial Demand (26 engines)	$3,924,180
10% Increase in Demand (58 engines)	$4,375,092
10% Decrease in Demand (48 engines)	$3,622,320
20% Increase in Transport Costs	$5,953,702
8% Increase in Transport Costs	$2,664,591

Surface

	20' Containers	No. of Engines Added
Initial Demand (26 engines)	$1,665,068	10
10% Increase in Demand (58 engines)	$1,842,673	11
10% Decrease in Demand (48 engines)	$1,605,112	10
20% Increase in Transport Costs	$2,062,725	10
8% Increase in Transport Costs	$1,417,295	10

Surface

	40' Containers	No. of Engines Added
Initial Demand (26 engines)	$1,840,520	14
10% Increase in Demand (58 engines)	$1,997,728	15
10% Decrease in Demand (48 engines)	$1,705,808	13
20% Increase in Transport Costs	$2,145,009	14
8% Increase in Transport Costs	$1,651,488	14

shipments in international distribution of various commodities, especially when water movements are part of the transportation network. The following points are made to justify the use of intermodal container systems:

1. Containerized loads offer a decrease in port handling time. In handling the C-130 engine, on an individual basis, there is a decrease in environmental protection, cargo security, and flexibility of its intramodal potential. Further, utilizing the container, cost reductions in handling can be realized.

2. Containerization offers a reduction in cargo turn-around time. In reducing the amount of handling time associated with containerization, cargo can be transferred to other modes of transportation in a timely and efficient manner.

3. Containers provide temporary storage facilities. Containers are able to serve as temporary storage facilities at ports, terminals and bases, where warehousing space may be limited.

4. Reduction in the number of orders placed. As indicated by this study, containerization reduced the number of orders required by 75 percent, using 20 foot containers, and by 87.5 percent using 40 foot containers. A reduction in cargo documentation will be experienced because the container becomes a single item in the system, thus requiring documentation of the container, instead of its contents.

5. Labor costs in freight handling are reduced due to the increased use of automated material handling equipment.

6. Finally, containers are available in a variety of sizes, many of which are standardized for intermodal use.

It should be noted that one of the reasons that break-bulk shipping had less total costs than the container modes was that only 45 percent of the available container volume is used when transporting engines. Since container tariff rates are based on the container and not the contents, low utilization results in a high transportation cost per engine. It is recommended that studies be conducted to develop ways to put more engines in each container in order to drive down the transportation cost per engine. This and other recommendations for further research will be presented in a later section.

As a result of this study, the use of 20 foot containers appears to be more economically feasible than the 40 foot container. While the actual transportation costs for the 40 foot container is somewhat less than the 20 foot container's transportation costs, acquisition costs necessary in obtaining the additional engines is substantially more when the 40 foot containers are used. This additional cost should be weighed against the advantages of having the additional engines and should be considered before making any major decisions between the use of either type of container.

Recommendations for Further Study

The forecasted increase in transportation and fuel costs will impact the way of doing business and leads to the need for reevaluating all phases of transportation planning for peace time and for mobilization. For example, the increased use of containerization procedures, for all commodities of cargo, has created a new situation that requires further research in determining the most economical means of implementing container systems.

In hopes of improving the efficiency and effectiveness of our transportation network, the authors offer a series of additional recommendations for further research.

1. It is recommended that a feasibility study be done in the design and development of racks to be installed inside the containers to allow stacking capability for engines and other DOD major investment type items. This will allow for additional engine shipments, at no additional cost to DOD. It is noted that only 45 percent of each container is presently being used.

2. A limitation that may affect the amount of savings is the cost of engine damage if containerization is used. Since the proposed system is not in use, at this time, there was no means of obtaining cost-of-damage data, for a

satisfactory comparison to the current system. Therefore, it is recommended that a cost study be done to determine damage cost data, which would then be added as a component to the total cost model for further analysis.

3. An area of concern, which may assist in cutting excessive transportation and fuel costs, is depot level maintenance to be performed in the European theater. It is recommended that a feasibility cost study be done on the construction of consolidated maintenance facilities in overseas locations. This would minimize the need for pipeline inventory and reduce total transportation costs to an absolute minimum. In essence, the DOD should research the size of the overseas maintenance facilities necessary to maximize economies of scale while providing the necessary support required.

4. The question of whether to lease or buy the number of containers necessary to support the shipment of the C-130 engines from CONUS to Europe should be investigated. A cost analysis should be performed in determining the total cost to acquire the necessary number of containers and the total cost of leasing. Break-even analysis should then be performed in determining a pay-off factor between the two concepts.

5. The final recommendation for further research concerns an investigation of the impact of using container systems on the MAC airlift system. That is, this study was

limited to an economic analysis to determine the least total cost system of moving C-130-7 engines between the CONUS and Germany. If containerships are used, there will be less traffic for the MAC airlift system to handle. The impact of this change on the use and readiness of the airlift system would have to be investigated.

Conclusion

The essence of this research involved a trade-off analysis between using a distribution system with premium transportation and no additional inventory versus a distribution system with surface transportation and additional inventory. This trade-off analysis is generally illustrated in textbooks as shown in Figure 4-1 (6:31).

However, the quantitative analysis conducted as part of this research effort indicates the shape of the total cost curves to be more like those shown in Figure 4-2. This figure indicates that surface transportation systems, coupled with additional levels of inventory, result in lower total costs when transportation costs increase at a faster rate than general prices.

Based on the results of this study, it is concluded that the proposed system, using either 20 foot or 40 foot containers, would be more economical than the continued use of air transportation for C-130-7 engine movement to and from Rhein-Main AB, Germany.

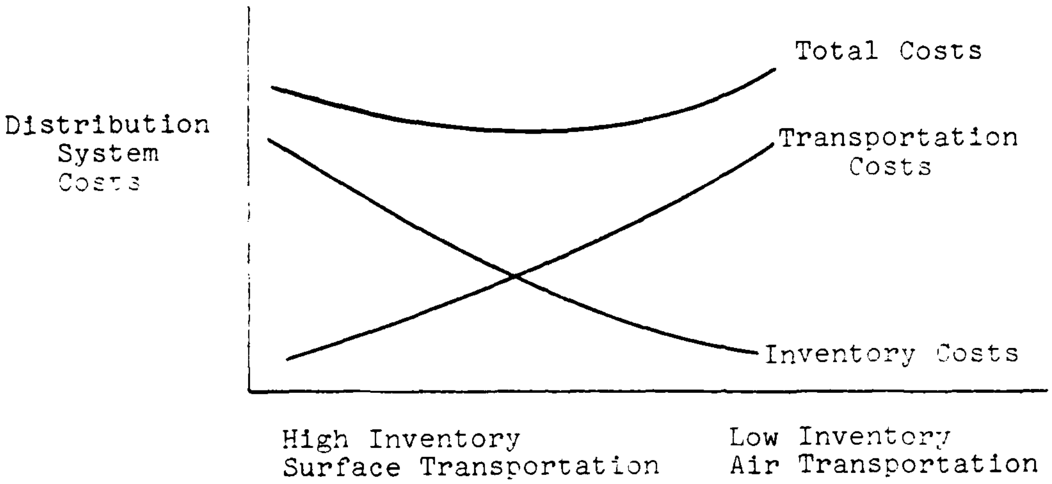

Fig. 4-1. Distribution System Cost Relationships

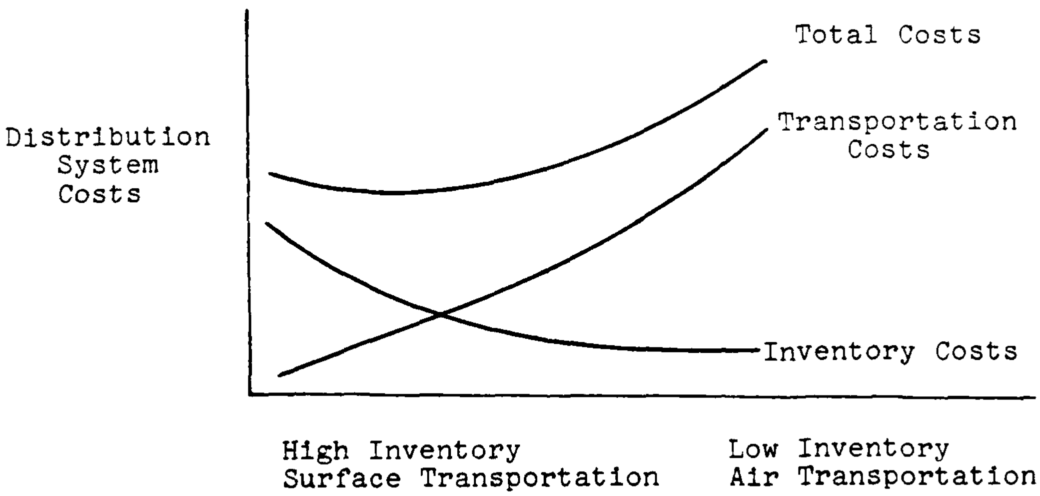

Fig. 4-2. Distribution System Cost Relationships

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